



State of New Jersey

OFFICE OF THE ATTORNEY GENERAL
DEPARTMENT OF LAW AND PUBLIC SAFETY
DIVISION OF LAW
25 MARKET STREET
PO Box 093
TRENTON, NJ 08625-0093

PHILIP D. MURPHY
Governor

SHEILA Y. OLIVER
Lt. Governor

GURBIR S. GREWAL
Attorney General

MICHELLE L. MILLER
Director

August 22, 2019

Hon. Esther Salas, U.S.D.J.
Martin Luther King Building & U.S. Courthouse
50 Walnut Street Room 4015
Newark, NJ 07101

Re: NEWC v. Newark, et al.
Civ. No. 2:18-cv-11025-ES-CLW

Dear Judge Salas:

We represent Defendant Catherine R. McCabe, Commissioner of the New Jersey Department of Environmental Protection ("Department"). During oral argument on August 16, 2019, the Court asked for evidence showing that the Department designated optimal corrosion control treatment for Newark back in the 1990s. (T95, T118)¹. By this filing, I am attaching the letters the Department has identified to date designating corrosion control treatment in Newark.

Enclosed as Exhibit A is Newark's June 30, 1994 corrosion control study for the Pequannock service area. The report included Newark's evaluation and conclusion that the use of silicate

¹ "T" refers to the transcript of the August 16, 2019 hearing.



August 22, 2019

Page 2

optimized corrosion control. (Ex. A, at 71-77). Enclosed as Exhibit B is the Department's August 8, 1995 letter approving Newark's corrosion control study and designating silicate as the corrosion control treatment for the Pequannock service area. The letter required Newark to install the corrosion control treatment by July 1, 1997 (Ex. B, ¶ 2), as required by 40 C.F.R. § 141.81(d)(4), and to continue monitoring water quality parameters (Ex. B, ¶ 3.b), as required by 40 C.F.R. § 141.81(d)(5). The letter also states that the Department would designate final water quality parameter ranges. (Ex. B, ¶ 4). Although the Department has not yet located its letter designating water quality parameter ranges, the Lead and Copper Rule ("LCR") requires the water quality parameter of pH to be in the range of 7.0 or higher. 40 C.F.R. § 141.82(f)(2).

As the Court is aware, the North Jersey District Water Supply Commission provides water to Newark's Wanaque service area. Enclosed as Exhibit C is the Department's June 15, 1995 letter approving the Commission's corrosion control study and designating orthophosphate as the corrosion control treatment. The Department required all water systems that receive water from the Commission, including Newark, to either submit a letter accepting the Commission's study and recommendation or to supply their own recommendation. (Ex. C, at 1). The Department required the Commission to install its corrosion control by January 1, 1997.

August 22, 2019

Page 3

(Id.) The Department also stated that the Commission would be required to maintain water quality parameters designated by the Department. (Id., at 1-2). Although the Department has not yet located its letter designating water quality parameter ranges for the Commission, as mentioned above, the LCR requires a pH range of 7.0 or higher. 40 C.F.R. § 141.82(f)(2).

At the same time, the Department highlights that its initial designation of corrosion control treatment and water quality parameters in the 1990s ultimately has no bearing on this lawsuit. The LCR contemplates that water systems that have optimized corrosion control in the past may subsequently exceed the lead action level, which is why the LCR requires each water system to continue monitoring its tap and source water for lead after the water system is deemed to have optimized corrosion control. 40 C.F.R. §§ 141.86(d)(2), (3), (4); 141.88(c), (d), (e). As the Plaintiffs concede, exceeding the action level is not a violation of the LCR. (T89); see also 40 C.F.R. §§ 141.81(b)(3)(v), 141.81(e)(1). Rather, the action level triggers additional requirements, § 141.80, including studying the corrosion control treatment, § 141.81(e)(3). Such studies may result in a recommendation to change such treatment.²

²In light of the fact that water systems may be subject to changes in their corrosion control treatment, the EPA only requires States to retain their corrosion control treatment and water quality

August 22, 2019

Page 4

On March 15, 2019, Newark completed its study and recommendation for the Pequannock service area (Ex. D), and on April 25, 2019, the Department designated optimal corrosion control treatment for this service area, (Ex. E). On May 7, 2019, Newark began dosing the water with the new corrosion control inhibitor. Although the LCR provides the water system 36 months to complete follow-up sampling before water quality parameters are designated, 40 C.F.R. § 141.81(e)(6), Newark agreed in the Supplemental Consent Agreement and Order ("SCAO") to complete the follow-up sampling within 24 months. (Ex. F, ¶ 35.A). The Department designates optimal water quality parameters within six months of receiving the sampling results. See 40 C.F.R. § 141.81(e)(7).

On June 28, 2019, Newark submitted its corrosion control study for the Wanaque service area. (Ex. G). The report is currently under review. Under the LCR, the Department has six months to designate optimal corrosion control treatment, which would be January 29, 2020. See 40 C.F.R. 141.81(e)(4). But, the Department anticipates issuing a decision sooner.

parameter designations for twelve years. 40 C.F.R. § 142.14(d)(8)(iii), (iv).

August 22, 2019

Page 5

Respectfully submitted,

GURBIR S. GREWAL
ATTORNEY GENERAL OF NEW JERSEY

By: s/ Andrew Reese
Andrew Reese
Deputy Attorney General

Encl.
c.: via CM/ECF

Exhibit A

Newark

Sharpe James
Mayor

Alvin L. Zach, P.E.; L.S. Director
Department of Engineering

Daniel Berardinelli, P. E., Manager
Division of Water/Sewer Utility
1294 McBride Avenue
Little Falls, New Jersey 07424
(201) 256-4965

Fax Telephone Numbers

Little Falls Office	(201) 256-7383
Central Avenue	(201) 643-6286

Mr. Barker Hamill
Chief, Water Supply Element
NJDEP & E
Bureau of Safe Drinking Water
CN 426
Trenton, NJ 08625.

City Engineer
Bloomfield
and
Belleville

June 30, 1994

RE: PWS ID# 0714001. Corrosion optimization study report.

Dear Mr. Hamill:

Enclosed are two copies of the corrosion optimization study report for the City of Newark's Water System. This report was prepared after an extensive demonstration testing program conducted in house. The City recommends the use of sodium silicate as the optimal corrosion inhibitor to be fed at the Pequannock Treatment Plant.

A copy of this report is also being forwarded to the Townships of Bloomfield and Belleville to whom we supply wholesale water.

The contact person for any inquiries on this report is Mr. Sanjeev Varghese, Principal Engineer, Hydraulics, who can be reached at 201-256-4965.

Very truly yours,


Daniel Berardinelli, P.E.
Manager, Div. Water/Sewer Utility

svhamill

encl: as above.

cc: Alvin Zach, P.E., Director, Engineering Department.
Andrew Pappachen, Supervising Engineer.
✓Anthony DeBarros, Principal Engineer, Hydraulics.

CITY OF NEWARK

**Report
on**

CORROSION OPTIMIZATION STUDY

Division of Water/Sewer Utility
1294 McBride Avenue
Little Falls, NJ 07424

June 1994

INDEX

No.	Item	Page
1.0	Introduction	2
1.1	Abstract	3
1.2	Background	3
1.3	Preliminary screening	12
1.4	Constraints	16
2.0	Bench scale testing	19
2.1	Approach	20
2.2	Results	21
3.0	Pilot testing	23
3.1	Flow through testing protocol	24
3.2	CHEMQUIPP pipe loop	24
3.3	Treatment schemes	27
3.4	Data handling & Analysis	27
3.5	Quality assurance & control	29
3.6	Criteria for optimum treatment	29
3.7	Initial stabilization period	30
3.8	Initial treatment period	39
3.9	Final treatment period	62
4.0	Comparison of alternatives	71
4.1	Assessment of orthophosphate	72
4.2	Assessment of blended phosphate	72
4.3	Assessment of silicate	72
4.4	Overall assessment	73
4.5	Preliminary cost estimates	74
4.6	Selection matrix	77
5.0	Conclusion	78
5.1	Recommendation	80
6.0	Reference	81

1.0 INTRODUCTION

1.1 ABSTRACT

The Lead and Copper Regulation requires Corrosion Control Studies be performed by large Public Water Systems (PWS) who exceeded the lead or copper action levels (AL). The City of Newark's Water system exceeded the action level for lead during the initial two six-month monitoring periods.. The Corrosion Optimization Study Report the City of Newark was prepared after an extensive in-house study.

1.2 BACKGROUND

HISTORY

The City of Newark's water system is one of the largest and oldest systems in New Jersey State. Presently the System serves approximately 275,000 population in Newark and another 200,000 in various other municipalities. There are approximately 500 miles of water mains in the city's distribution system. Mains within the City are primarily made of cast iron and date back to the 1800's. Pipes recently installed have been made of ductile iron. There are approximately 50,000 water service connections and 40% of them have lead service lines. The water pressure in the general purpose supply system ranges from 40 to 110 psi. The City's water system is a complex network of reservoirs, water treatment plants, transmission lines and pumping stations. Although still predominantly a gravity fed system, the recent construction of new interconnections and pumping stations has provided the City with back up sources of supply from the Passaic Valley Water Commission, the City of Jersey City, the North Jersey District Water Supply Commission and the Elizabethtown Water Company.

The City of Newark has two main sources of water supply - the Pequannock System and Wanaque System (North Jersey District Water Supply Commission). The Pequannock Water System draws its water from the five storage reservoirs at the Pequannock watershed. The water system serves the South Ward, West Ward, part of the North Ward and Central Ward. It also serves the Township of Belleville and Bloomfield. Water in this system is treated in the new Pequannock Water Filtration Plant. The treatment consists of prechlorination, alum addition, high rate

gulation, filtration and post chlorination. Typical raw water characteristics for the Pequannock system is given in Table 1. Water from the Pequannock Plant goes to an open balancing reservoir located at Cedar Grove. Water is sent through the Valley Road Rechlorination Plant where Sodium Hypochlorite is used as the disinfecting agent.

TABLE 1.1

Typical Raw Water Characteristics for Pequannock Water	
CHARACTERISTICS	RANGE
Alkalinity (mg/l) as CaCO ₃	22 - 35
pH	6.2 - 6.9
Turbidity (NTU)	1.0 - 2.5
Color (CU)	10 - 25
Hardness (mg/l) as CaCO ₃	24 - 45
Iron (mg/l)	0.1 - 0.3
Sulfate (mg/l)	5 - 25
Silica (mg/l)	4.0
Manganese (mg/l)	0.01 - 0.06
Dissolved Inorganic Carbonates (DIC) mg/l as CaCO ₃	48-49
Chloride (mg/l)	6 - 32
Temperature °C	1 - 20

The City also serves water to the following Municipalities.

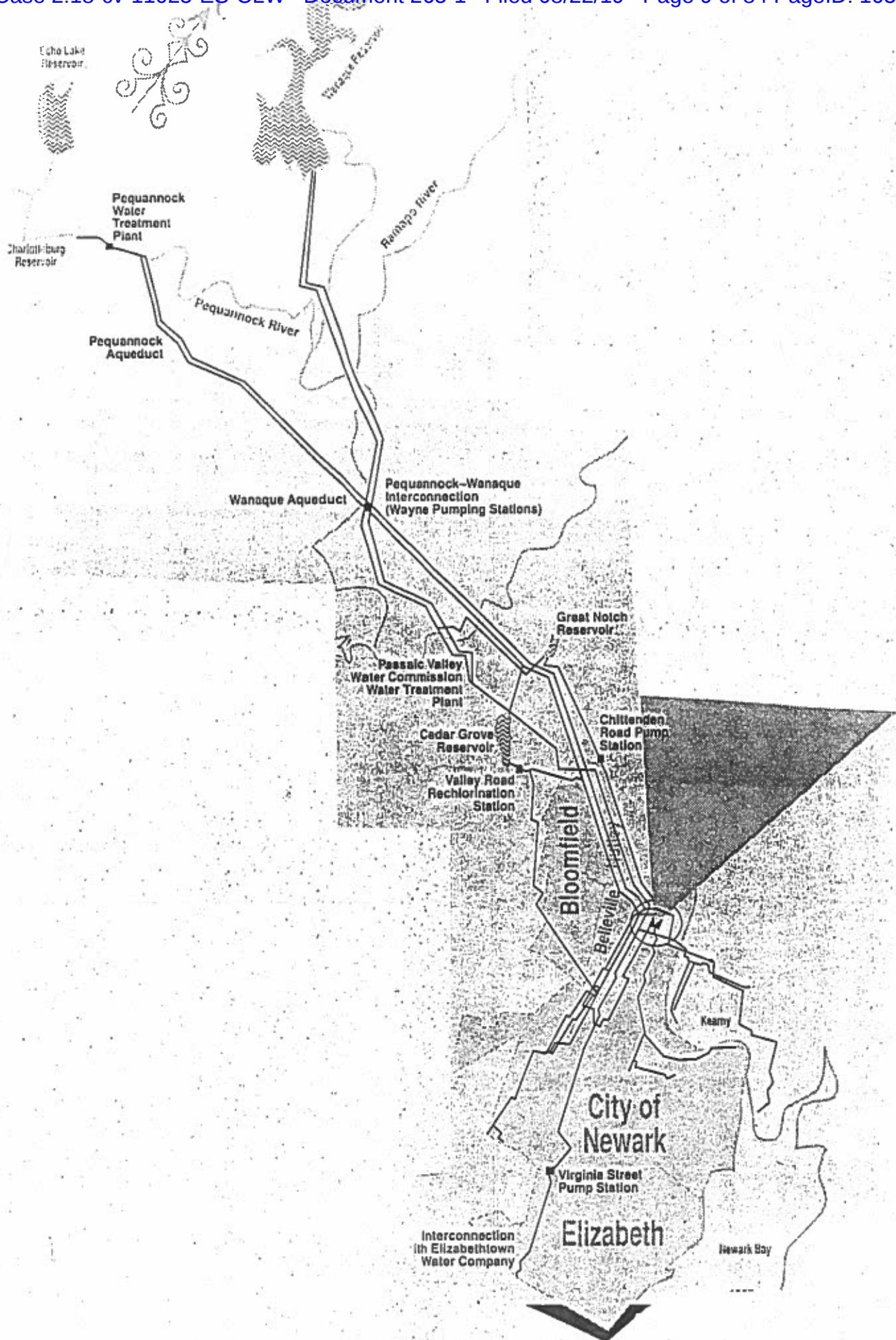
Table 1.2

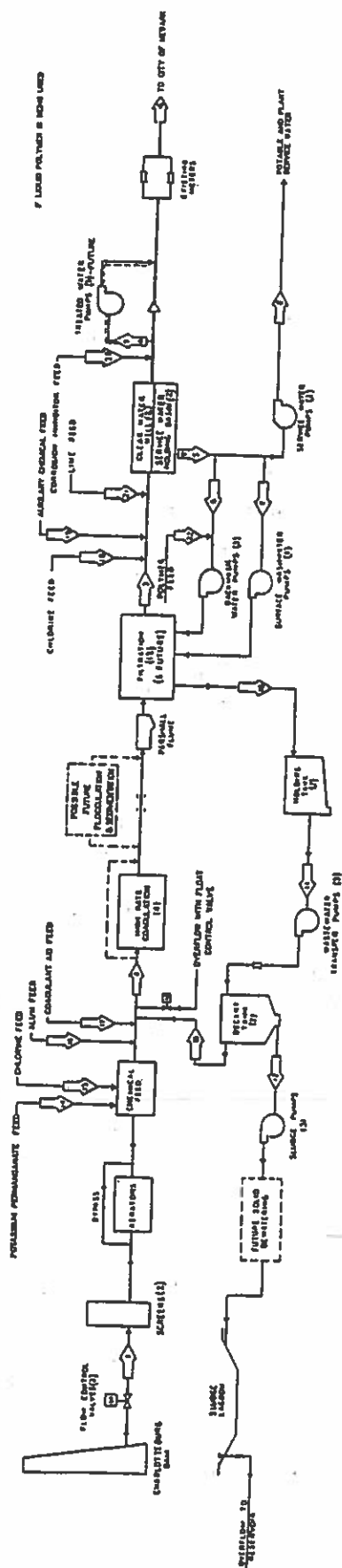
System	Municipality	Average Daily Usage
Pequannock	Belleville	3.8 mgd*
Pequannock	Bloomfield	5.8 mgd*
Wanaque	City of Elizabeth	6.0 mgd*

*mgd- million gallons per day

The second system, the Wanaque, serves Newark's East ward, part of the Central ward and part of the North Ward. It also serves the City of Elizabeth. The City of Newark owns a 40.5% share of water from the North Jersey District Water Supply Commission. Also the City is a participant in the Wanaque South Project and owns a 28.68% share. The primary transfer point from NJDWSC to Newark is at a regulator chamber located at the Belleville Reservoir site. The secondary transfer point is Newark's Wayne pumping station at which NJDWSC water is transferred to the Pequannock aqueducts. Raw water from the Wanaque Reservoir undergoes conventional surface water clarification/filtration at the NJDWSC's treatment plant. The water transferred at Wayne goes to the Cedar Grove open reservoir and get mixed with the Pequannock water.

Newark has an interconnection with NJDWSC at Wayne (Wayne Pump Station), with Passaic Valley Water Supply Commission and Jersey City at Chittenden Rd. Pumping Station, and with the Elizabethtown Water Company at Virginia St. pumping Station.



[illegible]

PROCESS SCHEMATIC
NOT TO SCALE

How To Seal

HAZEN and SAWYER - CLINTON BOBERT ASSOCIATES
A JOINT VENTURE

A JOINT VENTURE

CITY OF NEWARK

PEQUANNOCK WATER
TREATMENT PLANT

OPERATION AND MAINTENANCE MANUAL

OPERATION AND MAINTENANCE MANUAL

OPERATION AND MAINTENANCE MANUAL

Sources of Lead

As is typical of most water treatment plants, the treated water leaving Newark's Pequannock Treatment Plant or NJDWSC's Wanaque treatment plant contains insignificant amounts of lead. During the initial and final monitoring periods at the point of entry, lead (Pb/Cu-POE) was below the method detection levels. Hence the source of lead in drinking water is from the lead service lines, lead solder and brass fixtures at the customer's end. Each of these sources respond differently to corrosion inhibitors.

The Initial Monitoring Program

Newark completed the two required six month initial monitoring programs in 1992-93 for lead and copper. Initial monitoring activities included a material survey of the distribution system, preparation of a sampling plan, sampling and testing and reporting the results to the State. The sampling was carried out at the City's high risk sites. Water quality parameters were also measured at different locations of the distribution system. The City exceeded the action level for lead during both sampling periods.

Lead corrosion control study
Initial and Final Monitoring Results
 Lead Concentration Vs. Sample Number

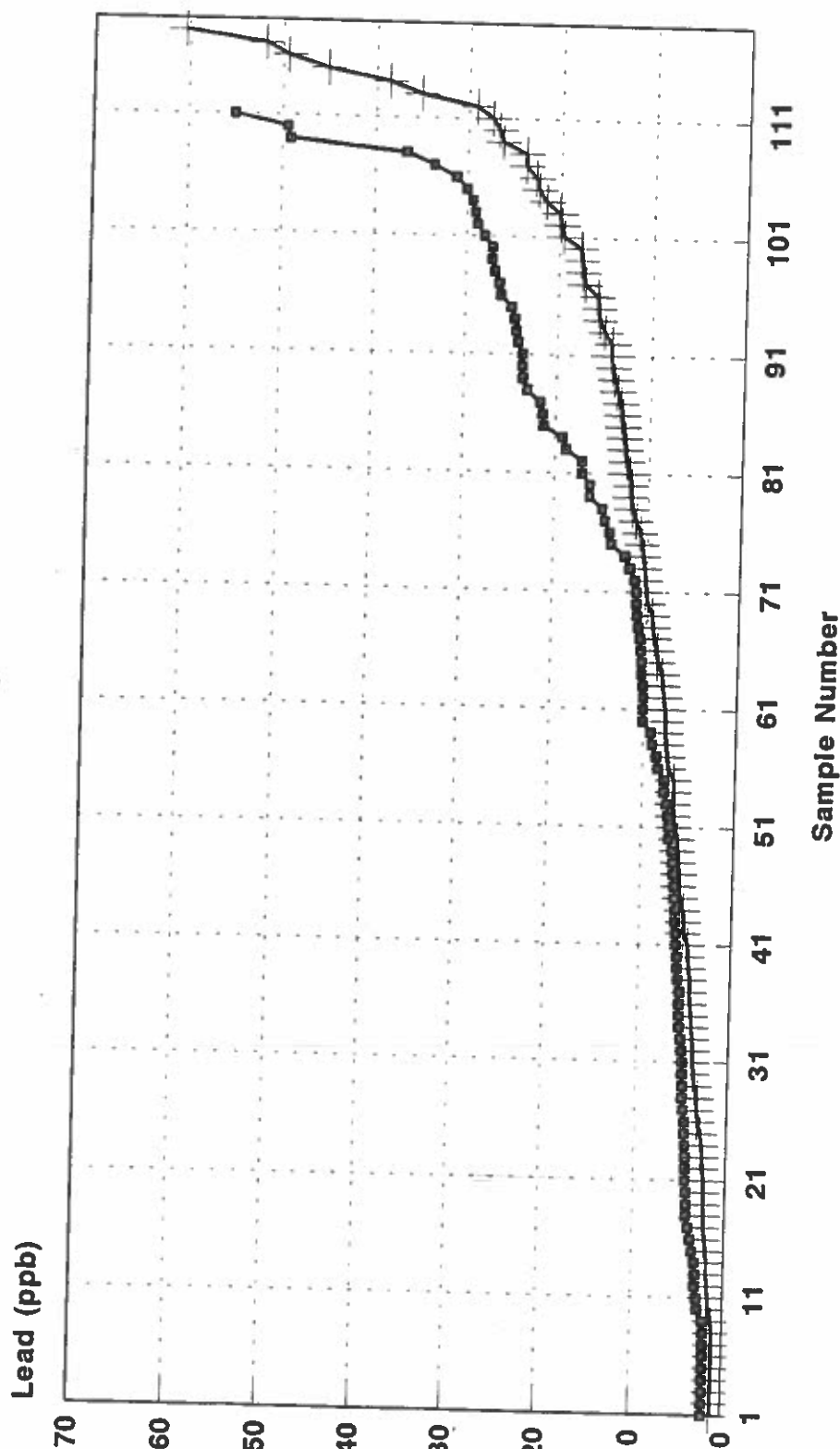


Figure 1.2
 Initial Monitoring + Final Monitoring

Lead Concentration Vs. Sample Number

Lead corrosion control study
Initial and Final Monitoring Results
 Copper Concentration Vs. sample Number

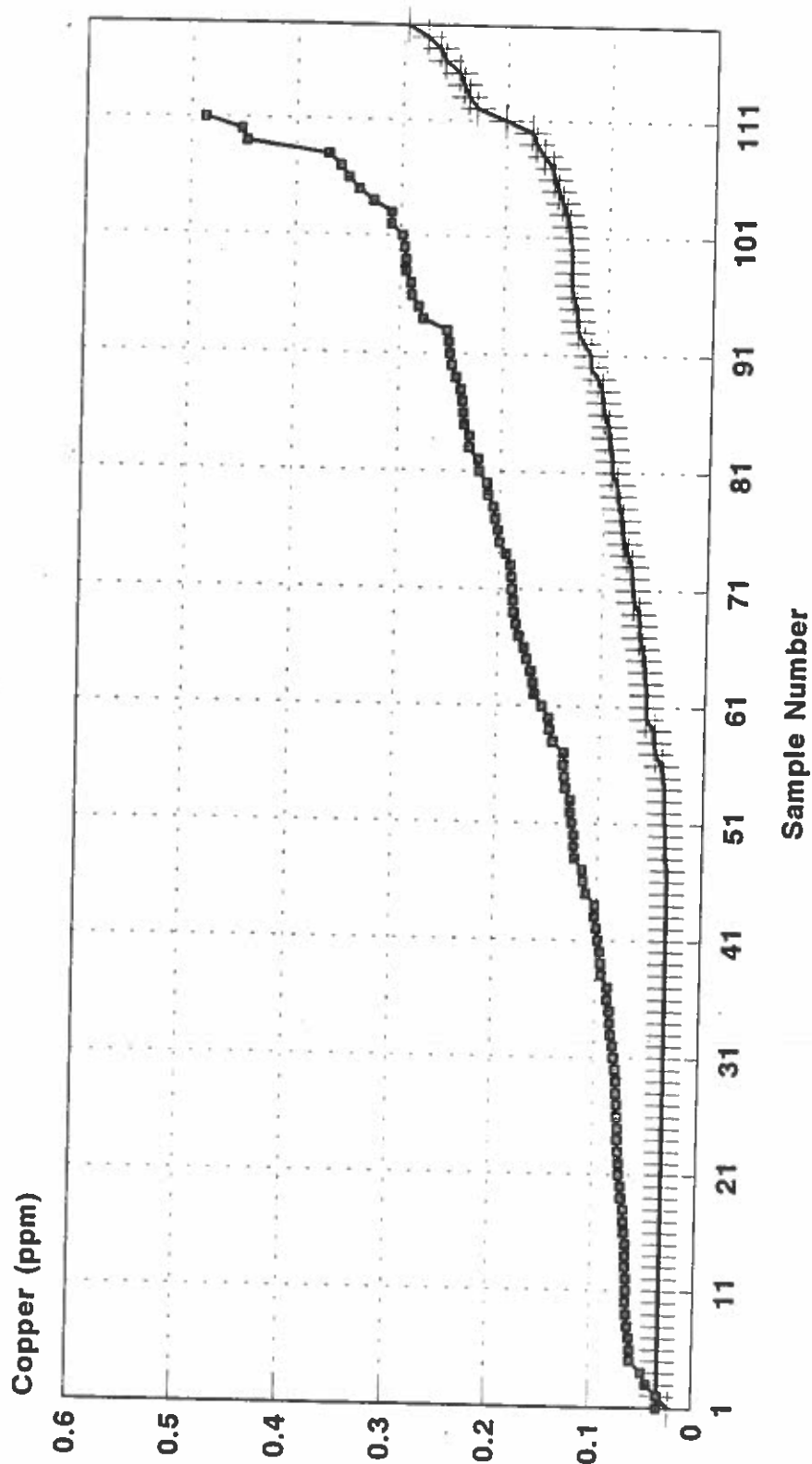


Figure 1.3
 Initial Monitoring Final Monitoring

Copper Concentration Vs. Sample Number
 Copper action level 1.3 mg/l

The results for copper analysis for both first round and second round sampling were well below the EPA action level. However, a higher concentration of copper was produced from first flush than water main samples, indicating considerable copper corrosion in the home plumbing.

Immediately after the initial monitoring sampling, the pH was raised to around 8.5 to study the effect of pH on the lead/copper leaching. As can be seen from the table below, pH did not make a significant change in the corrosion rate.

Table 1.3

<i>Item</i>	<i>1st Monitoring</i>	<i>2nd Monitoring</i>
Lead (ppb)	27.1	22.6
Copper (ppm)	0.294	0.156

1.3 Preliminary Screening

Principle of Corrosion

Corrosion causes the deterioration of crystalline structures that form the pipe materials, and can occur by one of the following three mechanisms: [a] Abrasion [b] Metabolic activity and [c] Dissolution. Abrasion is the physical removal of pipe material due to irregularities in the pipe surface which may dislodge at high fluid velocities. Metabolic activity refers to the utilization of the pipe material as a nutrient by the microorganisms. The dissolution of pipe material occurs when favorable water chemistry and physical conditions combine, generating the following possible corrosion scenarios.

1. Uniform Corrosion,
2. Concentration Cell Corrosion
3. Galvanic Corrosion.

Corrosion of drinking water distribution systems can result from any of the above mechanisms or combinations. Alterations of water quality characteristics by treatment can extensively reduce some corrosion activity. Corrosion control

principally is intended to inhibit dissolution. The objective is to alter the water quality such that the chemical reactions between water supply and the pipe materials favor the formation of a protective layer on the interior of the pipe walls. Coincidental reduction of other corrosion activity may be accomplished when dissolution of lead and copper are minimized. Abrasion of piping materials is typically accelerated when corrosion by products, such as tubercles, are present in the distribution system.

The three treatment approach which generally exists for control of lead corrosion are:

1. Carbonate Passivation.

This refers to the modification of pH and alkalinity to induce the formation of a less soluble compound on the targeted pipe materials.

2. Carbonate Precipitation.

This refers to the adjustment of pH, alkalinity and calcium to affect the calcium carbonate system equilibrium such that a tendency for calcium carbonate precipitation results.

3. Corrosion Inhibitors.

This refers to application of special chemicals characterized by their ability to form metal complexes and thereby reduce corrosion. This method employs passivation of the metal surface as the means of corrosion control. The generally available corrosion inhibitors are ortho-Polyphosphates and silicates.

Carbonate Passivation & Carbonate Precipitation.

Newark's Pequannock system was actively experimented with using Carbonate Passivation and to some degree Carbonate Precipitation after the initial lead monitoring period during 1992-1993 when the system pH was maintained in the range of 8.5 - 8.8. However, 1993 final monitoring results for lead indicated that the strategy is not sufficiently effective. The pipe loop study also showed that pH control could reduce the corrosion rate by 10%, but this was not sufficient to meet the action level. Furthermore, carbonate passivation at higher pH is unlikely to provide significant improvement and could result in reduced disinfection, higher disinfection by-products formation and more customer complaints.

Corrosion Inhibitors

Two predominant forms of corrosion inhibitors are available for potable water treatment. These are phosphate and silicate based compounds. Somewhat different chemical mechanisms of corrosion control and water quality criteria are associated with the effective use of phosphate and silicate based inhibitors. However, both utilize passivation as the method of providing corrosion protection. A number of corrosion inhibitors are commercially available on the market. As a direct additive to the drinking water supply, phosphates and silicates are subject to ANSI/NSF standards.

Phosphate Inhibitors

Lead forms an orthophosphate solid of low solubility under typical drinking water conditions, which serves as the basis of corrosion control. Copper solubility is not affected by the addition of phosphates. The pH range across which the orthophosphate appears to be most effective is 7.4 to 7.8. At pH values much above 7.8 metal phosphates precipitate causing scale formation and hydraulic capacity loss. Low hardness water is well suited for the use of orthophosphate inhibitors.

The critical parameters in using orthophosphate in corrosion control treatment are a) maintaining a stable pH in the inhibitor's effective range throughout the distribution system and b) determining the inhibitors composition best suited for the specific water quality objectives and conditions and also c) applying the appropriate dosage to accommodate background orthophosphate demand as well as the corrosion control protection required. Phosphate based inhibitors are acidic in nature and the pH effect of their addition to the finished water must be considered in determining the suitability of their application.

As mentioned earlier phosphates are effective only over a constrained pH range. Maintaining that range throughout the distribution system is an important component of implementing a successful corrosion control program. Systems with poorly buffered water have to install treatment to stabilize pH in addition to installing a corrosion inhibitor system for reducing the lead leaching rate.

Phosphate inhibitors are available in a variety of compositions, including sodium orthophosphate, zinc orthophosphate, polyphosphates and poly-ortho blended phosphates. Each of these compounds has different formulations as to effective phosphate present. Polyphosphate revert (hydrolyze) back to orthophosphate with time resulting in an increase in orthophosphate ion. This reversion is dependent on the pH and available metal ions. Polyphosphates sometimes increase corrosivity of water and the EPA suggests that polyphosphates should be used with caution because "their effects may be viewed in the extreme sense as an uncontrolled toxicological experiment on the general population". Polyphosphates are not recommended for corrosion control purposes in general, although, their application may be beneficial for other water quality concerns. The principal use is to sequester dissolved cationic constituents and reduce their ability to precipitate either in the distribution system or in the water treatment plant. Ortho-Poly phosphate blends offers some of the benefits of both.

Silicate Inhibitor

The corrosion inhibition by silicates is not yet well understood. It is known that soluble silicates are effective, environmentally safe chemicals which have been used to protect metals from corrosive effects of water. They are classified as corrosion inhibitors because they can deposit protective films onto various metal surfaces and can isolate the metal from further corrosion attack. They do not contribute zinc or phosphorus to the treated water. The most common form of silicate in the water treatment is 3.22 weight ratio sodium silicates. The method of controlling corrosion attributed to silicates appears to be a combination of adsorption and formation of less soluble metal-silicates compounds. They are considered as anodic inhibitors, combining with the free metal released at anode site of corrosion activity and forming an insoluble metal silicate compound. This material crystallizes to form a protective barrier on the face of pipe walls.

Similar to the use of orthophosphate inhibitors, silicates also combine with other constituents in the delivered water besides the material targeted for protection. Therefore sufficient dosage has be applied to compensate for the consumption of silicate by other metals or cations.

1.4 Constraints

Water quality constraints

The implementation of corrosion control can affect other water quality goals. The Lead and Copper Rule requires the Newark consider water quality constraints in assessing alternative corrosion control treatment, specifically, how an alternative treatment may adversely affect the other water quality goals. EPA recommends that all water quality constraints affecting Newark's system be identified and considered in the selection of treatment.

The impact of alternative corrosion control treatment on regulatory compliance with existing and probable future federal and State drinking water requirements is complex. Water quality constraints associated with the following key regulatory actions were considered during the screening of corrosion control alternatives.

[a] Surface Water Treatment Rule (SWTR)

Under this rule it is required that primary disinfection performance criteria be met. These criteria are pH dependent. Other conditions remaining the same, lesser inactivation of microbiological contaminants and improved corrosion control is achieved at higher pH.

[b] Total coliform rule (TCR)

This rule requires the wholesale purchasers to meet minimum occurrence standards for the occurrence of total and fecal coliforms in distribution system samples. Increasing the pH decreases the disinfection efficiency of the secondary chlorine residual, which may, in turn increase microbiological growth. The addition of phosphate based inhibitors increase the phosphorous content of a system. Phosphorus is an essential nutrient for microorganisms.

[c] Disinfectant and Disinfectant By-Products Rule (D-DBP)

Disinfectant by-products are regulated under this rule. Adjusting pH upward will affect the formation of certain DBP's, most notably trihalomethanes and haloacetic acids. These contaminants exhibit negative response to pH adjustment.

[d] *Enhanced Surfacewater treatment rule*

This rule is expected to impose greater disinfection requirements for systems with poorer source water.

Other constraints

[a] *Excess algal growth in open reservoir*

Phosphates are an important nutrient for algae. The introduction of phosphates into open an reservoir might result in a rapid growth of algae in the reservoir. Hence the centralized use of a corrosion inhibitor is restricted to a n o n phosphate based chemical.

[b] *Sodium*

Sodium is a major constituent in drinking water. The current MCL for sodium in drinking water is 50 ppm. Sodium is associated with high blood pressure and heart disease. USEPA has suggested a guidance level of 20 mg/l in drinking water for the protection of at-risk population, the population comprised of people predisposed to hypertension.

Newark's system has approximately 10 ppm of sodium. At a typical dosage of Sodium Silicate, the amount of additional sodium is less than 3 ppm. Hence, Newark is not affected by the constraint relating to sodium.

[c] *Other*

As mentioned earlier, Newark has an open reservoir which stores treated water.

The reservoir is located in Cedar Grove, halfway between the distribution system and the treatment plant. The average detention time in this reservoir is 12 days. Hence, the centralized application of a phosphate is out of the question as it will cause major algae problems in the open reservoir. Another alternative application point is after the Cedar Grove reservoir. But Newark has interconnections with other municipalities before the reservoir and supplies water to those municipalities on a seasonal basis. The City might have an onerous condition imposed on itself if it was required to build a number of satellite inhibitor feeding stations to provide the required corrosion control for the Municipalities.

Consumer complaints regarding red water, dirty water, color and sediment may result from the action of inhibitor on existing corrosion by-products within the distribution system. The City's past experience with a phosphate-based inhibitor substantiate this fact. The City used a polyphosphate as a corrosion inhibitor in the mid 1980's for about 2 years. The inhibitor applied at the treatment plant reverted to up to fifty percent orthophosphate and was detected upon entry into the open reservoir. The City was forced to stop the application after two years because of numerous dirty water complaints from the customers and a severe algae problem in the open reservoir.

Use of zinc-based phosphates may cause problems to the POTWs having zinc or phosphate limits in their NJPDES permit, especially the Passaic Valley Sewerage Commission.

The application of phosphate-based inhibitors to a system with existing corrosion byproducts can result in depletion of disinfectant residuals within the distribution system. Also under certain conditions phosphate-based inhibitors may stimulate the bio-film in the system. If corrosion by-products are released after the use of inhibitors, coliforms may be detected more frequently and confluent growth is more likely.

2.0 BENCH SCALE TESTING

2.0 BENCH SCALE TESTING

From the results of the initial monitoring, it was determined that the practice of only adjusting the pH is insufficient to maintain lead concentrations below the first flush action level of 15 ppb in 90% or more of the samples. Therefore, a second phase of testing was undertaken to determine if alternative corrosion control treatment would be more effective in reducing lead concentrations. The specific objective of bench scale testing was to evaluate a wide range of feasible options (specifically required by the Lead/Copper Rule) and to identify the two or three best options for longer duration pilot testing.

2.1 Approach

Several approaches were considered for short term bench scale testing. A two cell corrosion test device was used. Raw water was fed into the first cell. Cleaned pre weighed metal coupons of mild steel were suspended in both cells so that contact with water would be maintained. All of the metal coupons were of identical size and shape. A corrosion inhibitor was applied to the water before it reached the second cell. The following is a list of inhibitors used in the testing.

1. Lime
2. Orthophosphate
3. Ortho-Poly Blended Phosphate
4. Silicate

In accordance with the manufacturer's recommendation a higher than normal dosage of orthophosphate, blended phosphates and silicate was used in the initial passivation period. A silicate dosage of 20 mg/l was used for the initial one month passivation period and an orthophosphate dosage of 1 mg/l was used for the first two weeks of passivation. After the passivation a lower dosage of 9 mg/l of silica was used. In the pH inhibitor cell a pH of about 8.5 to 9.0 was maintained. The performance of the corrosion inhibitors is based on a function of weight loss by the metal coupons under test conditions lasting one month.

2.2 Results

The results of the bench-scale testing were variable and did not clearly show one of the inhibitors to be more effective than the other in reducing corrosion.. Early results probably varied because the new metal coupons were corroding rapidly during the initial passivation period. In addition certain inhibitors were reacting with preformed corrosion products, which were still incompletely formed on the coupon surfaces during the initial passivation period. During the final weeks of testing all inhibitors started showing consistent results. All reduced corrosion to a degree . The least effective one was pH adjustment, which showed approximately a 15% reduction of lead leaching.

The following table shows the results of the bench scale testing.

Table 2.1

Inhibitor	Percentage Reduction	Remarks
pH Adjustment	15%	Insufficient inhibition to achieve desired lead reduction
Orthophosphate	50%	Showed lead reduction Cannot be used before the open reservoir/requires satellite feeding stations
Blended Phosphate	40%	Showed lead reduction Cannot be used before the open reservoir/requires satellite feeding stations
Silicate	45%	Showed lead reduction Can be used in the treatment plant

From the results of the bench scale testing the following alternatives were eliminated from further desk top evaluation.

1. pH-Alkalinity Adjustment.
2. Calcium Adjustment
3. Corrosion Inhibitors:
 - a] Zinc Orthophosphate.
 - b] Poly Phosphate.

The following alternative were further evaluated in the Desk Top or Pilot Testing:

1. Non Zinc Orthophosphate.
2. Ortho-Poly Blended Phosphate
3. Silicate.

3.0 PILOT TESTING

3.0 PILOT TESTING

The purpose of Corrosion control testing is to demonstrate the relative performance of alternative treatment approaches and identify the optimal treatment. In order to determine the relative performance of the alternative treatment approaches, a control condition must be clearly defined through out the testing period.

3.1 Flow-Through Testing Protocol

The use of a flow through testing method to evaluate the corrosion control performance is preferred since it more accurately simulates the house plumbing condition, which is the major source of lead in the City's case. Flow through testing refers to continuous or cycled flowing conditions through a testing apparatus. The solution is not recirculated. Typically, flow through testing is used to describe pipe rig operations where pipe loops and coupons are attached to a central manifold which distributes the test water to one or more corrosion testing units.

3.2 Selection of Chemquip's CHEMCORR-LP Pipe Loop.

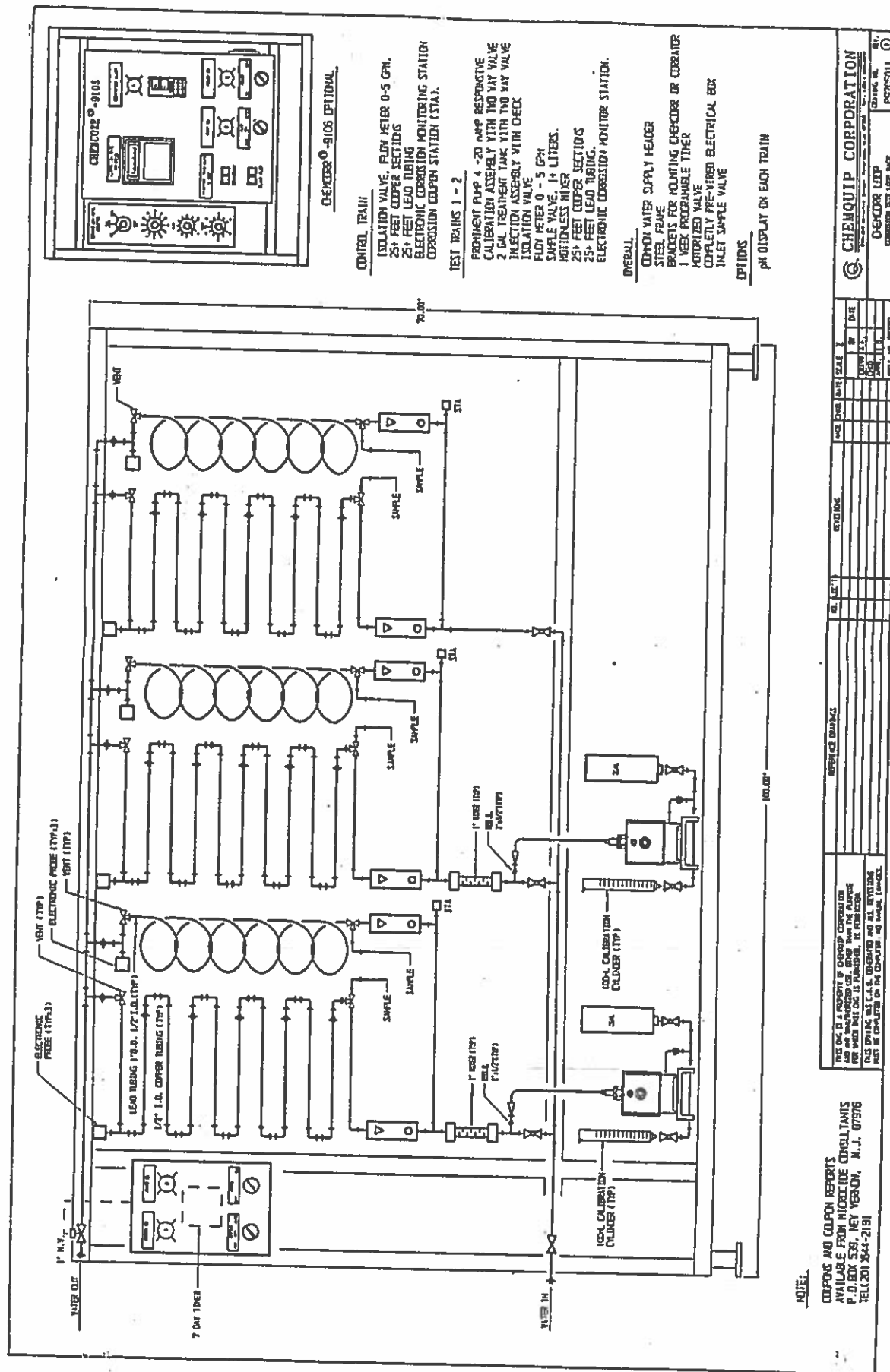
The City decided to use the Chemquip Corporation's CHEMCORR-LP Pipe Loop for the demonstration Testing after a study of available systems on the market. This is a pipe loop apparatus manufactured in accordance with AWWARF recommendations. It has 1/2" lead and copper loops and can study three corrosion conditions simultaneously. Finished water is directed to all the three trains. It simulates an eight hour dead leg condition using a timer, a motorized valve and a shut down device. This sample is a simulation of the first flush condition in homes. Flow is monitored and controlled through flow meters. Chemical treatment is monitored from treatment reservoirs and validated by 1000 ml calibration cylinders. Motionless mixers in the test trains insure complete mixing of the treatment chemicals when the water is flowing. A series of 25' of lead and copper lines in each train are available to detect changes in the corrosivity conditions over a period of time. The 25' allows exactly 1 liter of sample to be collected for each dead leg and sample is taken from each dead leg by means of a sample port and relief valve. A station is available on each train to provide electronic corrosion monitoring and readings are taken using corrosion rate probes.

Measurement of the corrosion rate is based upon the principle of corrosion. Corrosion is an electrochemical process whereby electrons flow from the anode to cathode in a conductive solution (water). As part of this electron migration, metal ions are liberated from anode to the conducting medium, water, and are transported to the cathode as the oxide form. Examples of this phenomena are lead oxide and ferric and ferrous oxides of iron, otherwise known as rust.

In this apparatus there are three principal ways of measuring the phenomena of corrosion. The first is by means of the metal ion in the solution. The second uses some pre-weighed coupons exposed for a fixed period of time, such as 30 days, and measures the weight loss over that time. The third type is the electronic corrosion rate. This uses the linear polarization technique and gives a read out in mils per year.

The same water is fed through all the three pipe loops. One loop of the three is kept as the control loop. CHEMCORR-LP can sense minute changes of water quality and can generate a response. It feeds the exact amount of inhibitor each time. The seasonal changes in the corrosion rate can be tracked accurately with this device.

During the testing finished water was sent through the pipe loop. Two of the pipe trains (each train contain one lead loop and a copper loop with lead solder) were used for corrosion control testing, where the third received no treatment and was used as a control loop. The corrosion control treatment schemes used by the two pipe train



sets were determined through the bench scale testing and included three corrosion inhibitors, orthophosphate, blended phosphate and silicates. One liter samples were taken each week from each three trains (six loops) to measure the changes in metal concentration, orthophosphate, total phosphate, silicate, pH, alkalinity and hardness and several other parameters.

3.3 Treatment Schemes

Initially the pipe loop ran without any addition of corrosion inhibitors for approximately six weeks to generate corrosion in the newly installed pipes in the loop and to flush out any material debris attached to the interior of the pipe material. During this period samples were collected on a regular basis and the water quality was monitored. By the end of sixth week all the pipe loops attained a steady state condition (Stabilization) and results started showing similar qualities. The flow rate in each pipe was maintained at one gallon per minute (1 gpm) to simulate a flow in a typical household service line. Water samples were collected once a week in the morning after the water had been standing in the pipe for 8 hours and before the flow was resumed. This sample represented the first flush concentration expected from household service. The first flush samples were analyzed for temperature, pH, alkalinity, calcium hardness, lead, copper, orthophosphate, total phosphate and silicate.

3.4 Data Handling And Analysis

The USEPA guidance manual provides very little direction on techniques to use for evaluation of data from corrosion studies. Extensive laboratory studies and EPA experience indicate that most traditional techniques such as computation of averages and t-test for comparison of means are largely inadequate because of the highly variable and usually non-normal data. Changes in metal leaching and film formation caused complexity because metal dissolution is often non-linear with respect to time. Furthermore, metal levels in water to which consumers are exposed have not been shown to correlate well with surrogate measurements such as corrosion rates.

When comparing the difference in corrosion treatment using corrosion studies, metal concentration in the water are the parameters of concern. Under the Lead and

Copper rule, the treatment that minimizes corrosion is considered optimum. Therefore if the lead concentration in the water is the parameter being used as the most important factor to measure corrosion effectiveness, the treatment that gives the lowest lead levels in the water is considered the optimum one. To compare lead levels in the water between two treatments, assuming Wilcoxon Rank Test would be applied. And if the populations are independent the Wilcoxon Signed Rank Test would be applied. The Wilcoxon Signed Test is analogous to pairing the data between control and treatment.

Pipe loops constructed for corrosion studies of lead and copper leaching containing new materials will exhibit a decreasing trend in lead and or copper levels over time as materials age. These materials stabilize after a certain period of time if the incoming water quality is relatively consistent. This stabilization may indicate that the pipe material has reached equilibrium with respect to corrosion or a state where film formation or transition becomes very slow. It may respond similarly to the plumbing material in the system. While it may be of interest to evaluate the entire set of data generated from the study, it is more appropriate to use only those data which have reached stabilization while determining the impact of various treatments on lead levels. Stabilization can be determined by visual examination of the data or by calculating an estimated trend for the data.

When reviewing the distribution of the data generated from a corrosion study, the tendency of a researcher is to discard several of the very high levels as outlier, or values which are abnormalous. By discarding these values, the mean level of the data will be lowered and there will be less variation in the data. Discarding high levels may seem particularly attractive when comparing the differences in lead levels measured from a control pipe rack and treated pipe racks.

It is important to note, however, that lead levels at the tap also exhibit high lead levels occasionally. The occurrence of unusually high lead levels is the evidence of complex chemical and physical factors which impact upon the amount of lead which may leach into the water.

So in summary, the following procedures were followed in data handling for the City's corrosion optimization study. The data was checked to determine whether it followed

the normal distribution using graphical techniques and numerical techniques. Then it was determined whether the data represented a stable population or whether there were still trends to chemistry evolution of the system. Appropriate comparison statistics at selected decision levels were made to the stabilized system. For normally distributed data, non parametric statistical procedures are used and for non normally distributed data Wilcoxin Signed Rank test was used.

3.5 Quality Assurance and Quality Control Program

Proper quality assurance and quality control procedures were followed during the testing program. Standing samples were taken every week and daily monitoring of water quality parameters was conducted for water supplied to the pipe rig.

Split samples were collected for metal analysis. Sample blanks and spikes were prepared by someone other than the chemist who was doing the analysis. All instruments were properly calibrated before the beginning of each metal testing period. Chemical feed rates were checked periodically to verify the feed rates. All sample handling procedures were followed for those required in the rule for metals and water quality parameters. The results were verified by comparing the results with that of an outside lab on a monthly basis.

3.6 Criteria for selecting optimum treatment

The following criteria were considered in its order of priority for selecting the optimum treatment.

1. Performance: Prime importance was given to the performance of the alternative treatment evaluated by the demonstration testing.
2. Feasibility of implementing the alternative corrosion control treatment.
3. Reliability features of the alternative treatment approaches based on treated water quality and full scale operational characteristics.
4. Costs associated with installation and operation, where alternative treatment have comparable performance.

3.7 Stabilization period With no treatment

The same quality water was run through all the loops to achieve an equilibrium condition. After 4 weeks the loops started showing similar lead and other water quality characteristics.

The following table represents the initial and final results during that period.

Table 3.1
Loop I Results : Copper pipe with lead solder
No treatment : Initial Stabilization Period

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>	<i>Alkalinity ppm of CaCO₃</i>	<i>pH</i>	<i>Hardness</i>
1	22	0.35	None	17.0	7.1	23.4
2	50.3	0.34	None	17.9	7.2	21.9
3	47.8	0.25	None	17.0	7.3	24.0
4	42.9	0.35	None	19.8	7.5	26.0
5	48.1	0.30	None	19.2	7.3	23.2
6	47.8	0.31	None	19.2	7.3	23.0

Table 3.2*Loop II Results : Lead Pipe*

No treatment : Initial Stabilization Period

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>	<i>Alkalinity ppm of CaCO₃</i>	<i>pH</i>	<i>Hardness</i>
1	490.0		None	17.0	7.1	23.4
2	378.0		None	17.9	7.2	21.9
3	420.0		None	17.0	7.3	24.0
4	373.0		None	19.8	7.5	26.0
5	437.0		None	19.2	7.3	23.2
6	437.0		None	19.2	7.3	23.2

Table 3.3*Loop III Results : Copper pipe with lead solder*

No treatment : Initial Stabilization Period

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>	<i>Alkalinity ppm of CaCO₃</i>	<i>pH</i>	<i>Hardness</i>
1	167.0	0.835	None	17.8	7.0	23.4
2	60.2	0.26	None	16.8	7.2	23.5
3	38.8	0.30	None	17.8	7.2	25.0
4	37.36	0.24	None	18.7	7.5	26.0
5	48.29	0.30	None	19.2	7.3	23.2
6	47.9	0.31	None	19.2	7.3	23.0

Table 3.4*Loop IV Results : Lead pipe*

No treatment : Initial Stabilization Period

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>	<i>Alkalinity ppm of CaCO₃</i>	<i>pH</i>	<i>Hardness</i>
1	422.0		None	17.0	7.1	23.4
2	-		None	17.9	7.2	21.9
3	350.2		None	17.0	7.3	24.0
4	374.2		None	19.8	7.5	26.0
5	430.0		None	19.2	7.3	23.2
6	428.5		None	19.2	7.3	23.0

Table 3.5*Loop V Results: Copper pipe with lead solder*

No treatment : Initial Stabilization Period

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>	<i>Alkalinity ppm of CaCO₃</i>	<i>pH</i>	<i>Hardness</i>
1	30.2	0.262	None	17.0	7.1	23.4
2	81.1	0.257	None	17.9	7.2	21.9
3	19.0	0.276	None	17.0	7.3	24.0
4	49.0	0.314	None	19.8	7.5	26.0
5	44.8	0.310	None	19.2	7.3	23.2
6	47.5	0.310	None	19.2	7.3	23.0

Table 3.6*Loop VI Results : Lead Pipe*

No treatment : Initial Stabilization Period

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>	<i>Alkalinity ppm of CaCO₃</i>	<i>pH</i>	<i>Hardness</i>
1	532.0		None	17.0	7.1	23.4
2	-		None	17.9	7.2	21.9
3	373.3		None	17.0	7.3	24.0
4	354.0		None	19.8	7.5	26.0
5	425.1		None	19.2	7.3	23.2
6	430.2		None	19.2	7.3	23.0

Lead corrosion control study
Initial Stabilization period-With no treatment
Lead results from lead pipe loops(II, IV & VI)

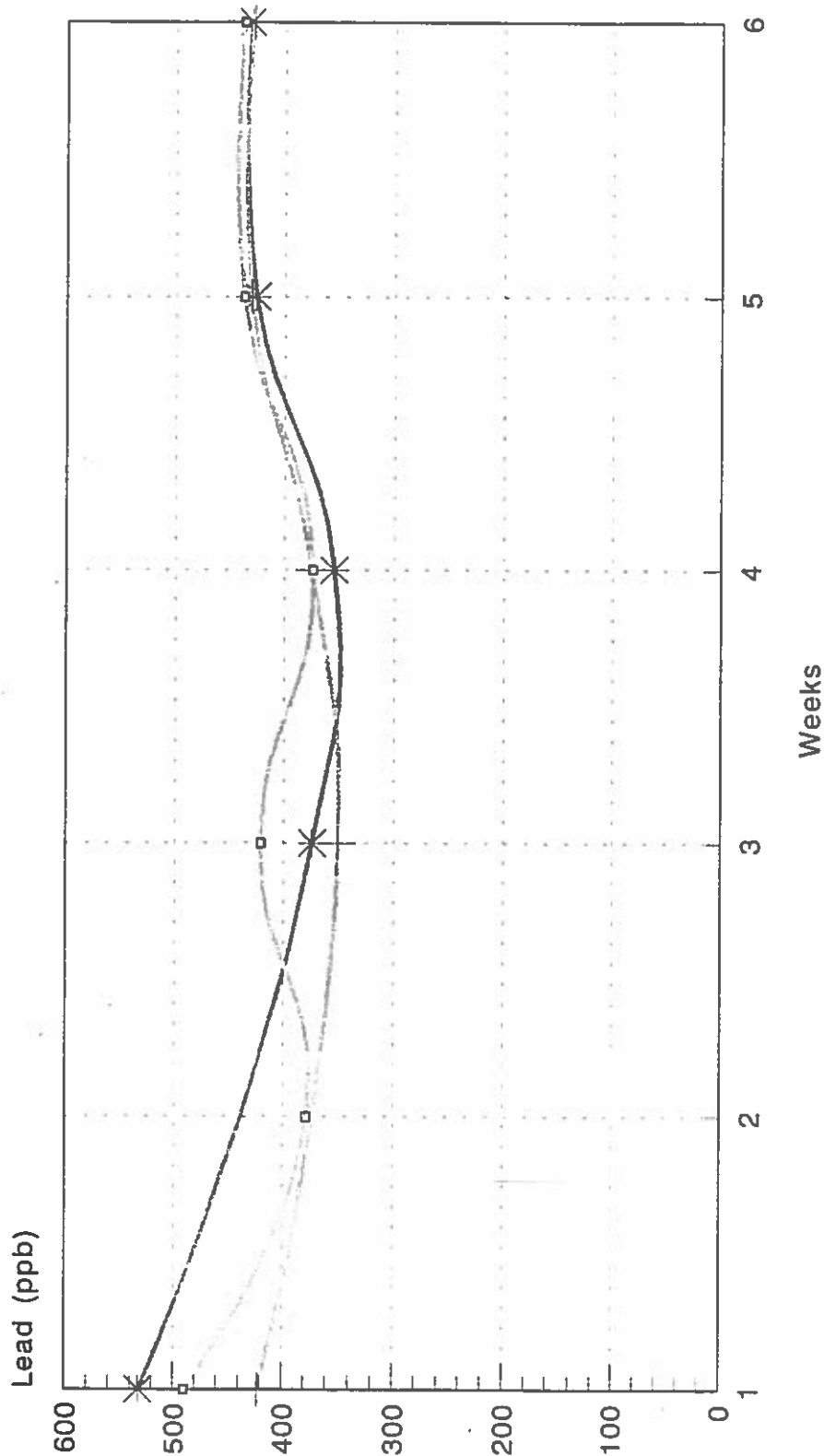


Figure 3.1
□ Loop II + Loop IV * Loop VI

Lead pipe loops-Lead results

Corrosion control study
Initial Stabilization period-With no treatment
Lead results from Copper pipes with lead solder joints

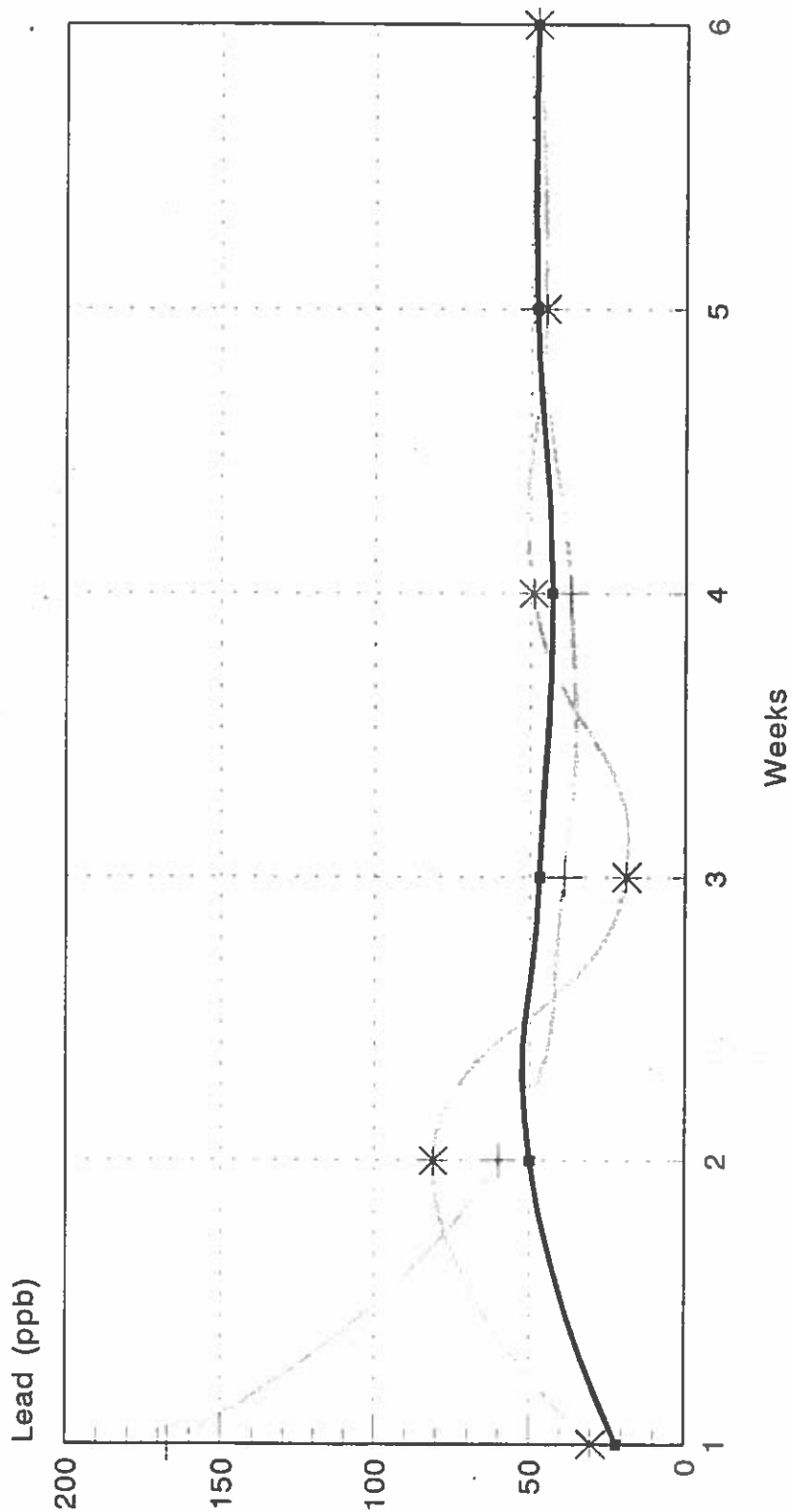


Figure 3.2
—■— Loop I + Loop III * Loop V

Copper with lead solder pipe loops-Lead Results

Lead corrosion control study
Initial Stabilization period-With no treatment
Copper results from Copper pipes with lead solder joints

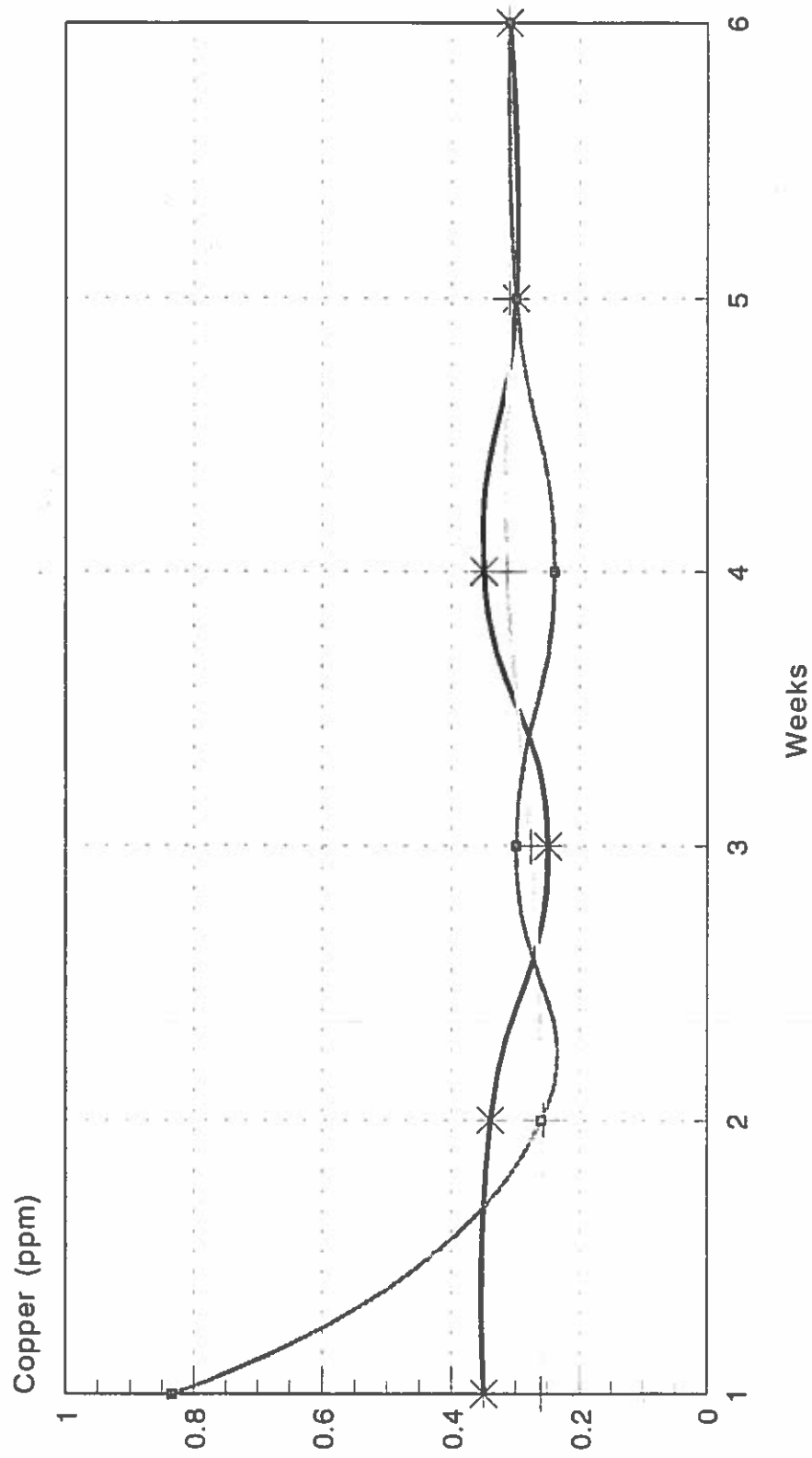


Figure 3.3
-□- Loop I + Loop III * Loop V
Copper with lead solder pipe loops-Copper Results

**Lead corrosion control study
Pipe insert (coupons) Results
Comparison of coupon weight loss & Corrosion rate**

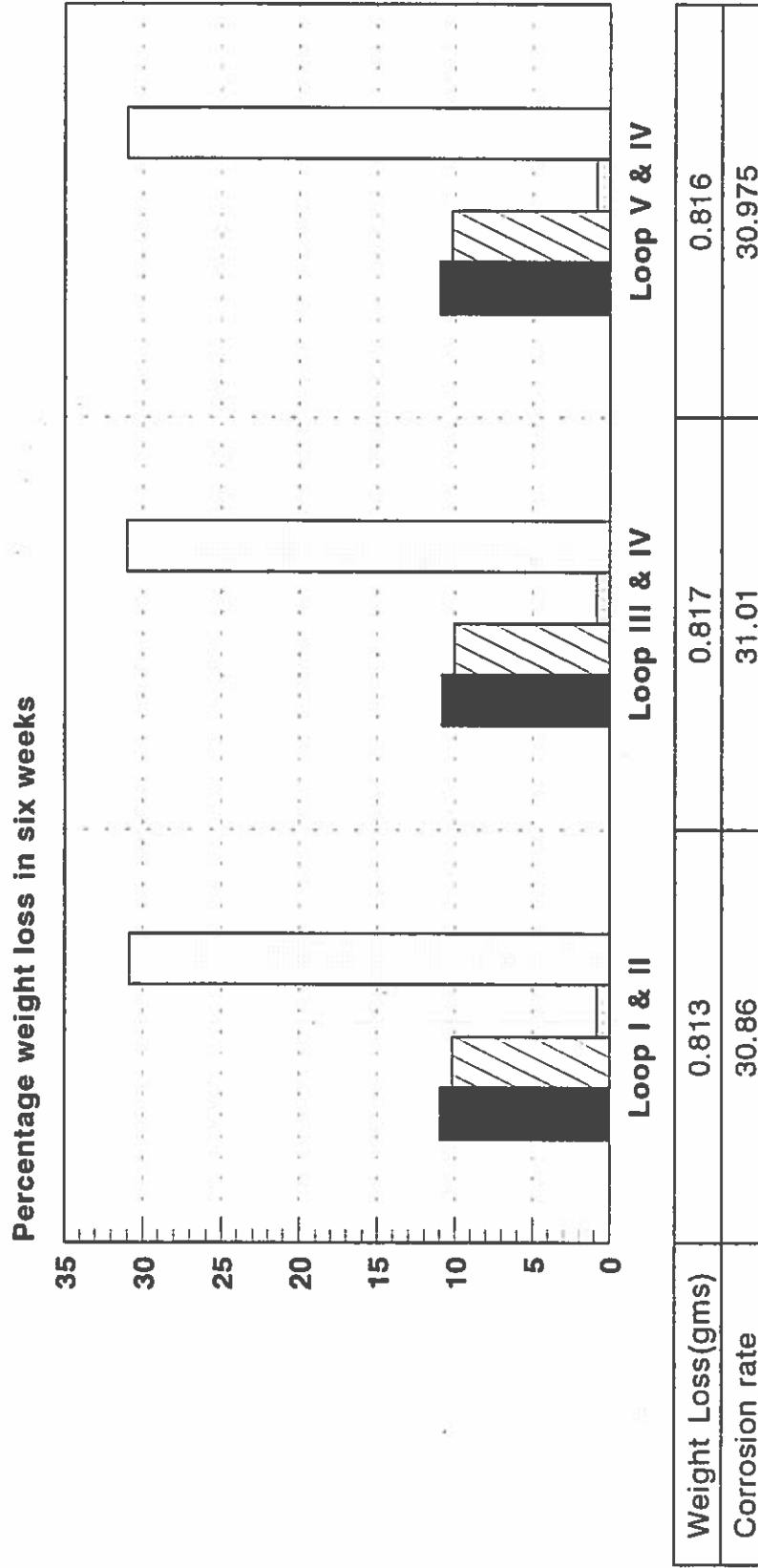


Figure 3.4

Initial Wt.(gms)
 Final Wt.(gms)
 Weight Loss(gms)
 Corrosion rate

Initial Stabilization Period (with no treatment)

Table 3.7*Initial Pipe insert results (mild steel coupons)*

No treatment : Initial stabilization Period (6 weeks)

<i>Train</i>	<i>Initial Weight (grams)</i>	<i>Final Weight (grams)</i>	<i>Percentage of Weight loss (%)</i>
Train 1	10.993	10.180	7.4 %
Train 2	10.885	10.068	7.5 %
Train 3	11.015	10.199	7.4 %

**Lead corrosion control study
Pipe insert (coupons) Results
Comparison of coupon weight loss & Corrosion rate**

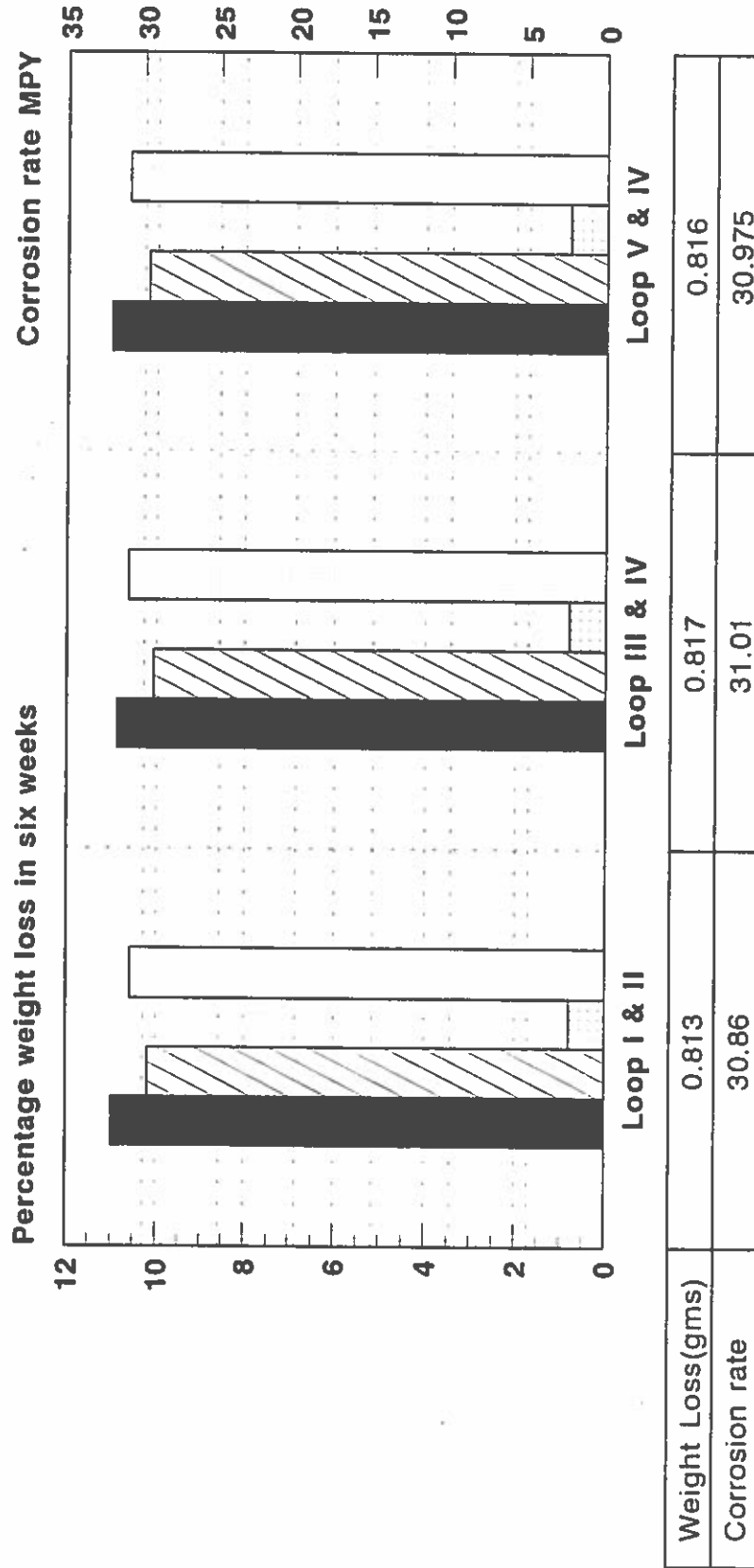


Figure 3.4

Initial Wt.(gms)
 Final Wt.(gms)
 Weight Loss(gms)
 Corrosion rate

Initial Stabilization Period (with no treatment)

3.8 Initial period with treatment

Orthophosphate was added as the inhibitor in the first loop for three months, silicate was added in the second train and the third train was kept as the control.

Following table is the summary of results from the first three months with treatment

Table 3.8
Loop I: Copper Pipe Loop with Lead Solder

Orthophosphate is added in this loop

<i>Week</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>
7	137.0	0.009	1
8	31.3	0.190	1
9	13.64	0.078	1
10	36.7	0.264	1
11	75.0	0.227	1
12	32.0	0.0913	1
13	15.14	0.045	1
14	11.2	0.039	1
15	12.31	0.03	1
16	7.6	0.03	1
17	5.2	0.019	1
18	5.32	0.021	1
19	6.84	0.018	1
20	16.56	0.01	1

<i>Week</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>
21	13.27	0.01	1
22	12.15	-	1
23	10.0	0.106	1
24	7.5	0.062	1
25	28.4	0.084	1
26		24.9	None
<i>Stopped orthophosphate treatment on 26th week</i>			

The following figure gives the graphical representation of the lead and copper concentration during that testing period of time.

**Lead Corrosion control study
Loop I: Copper pipe with lead solder joints
With orthophosphate treatment**

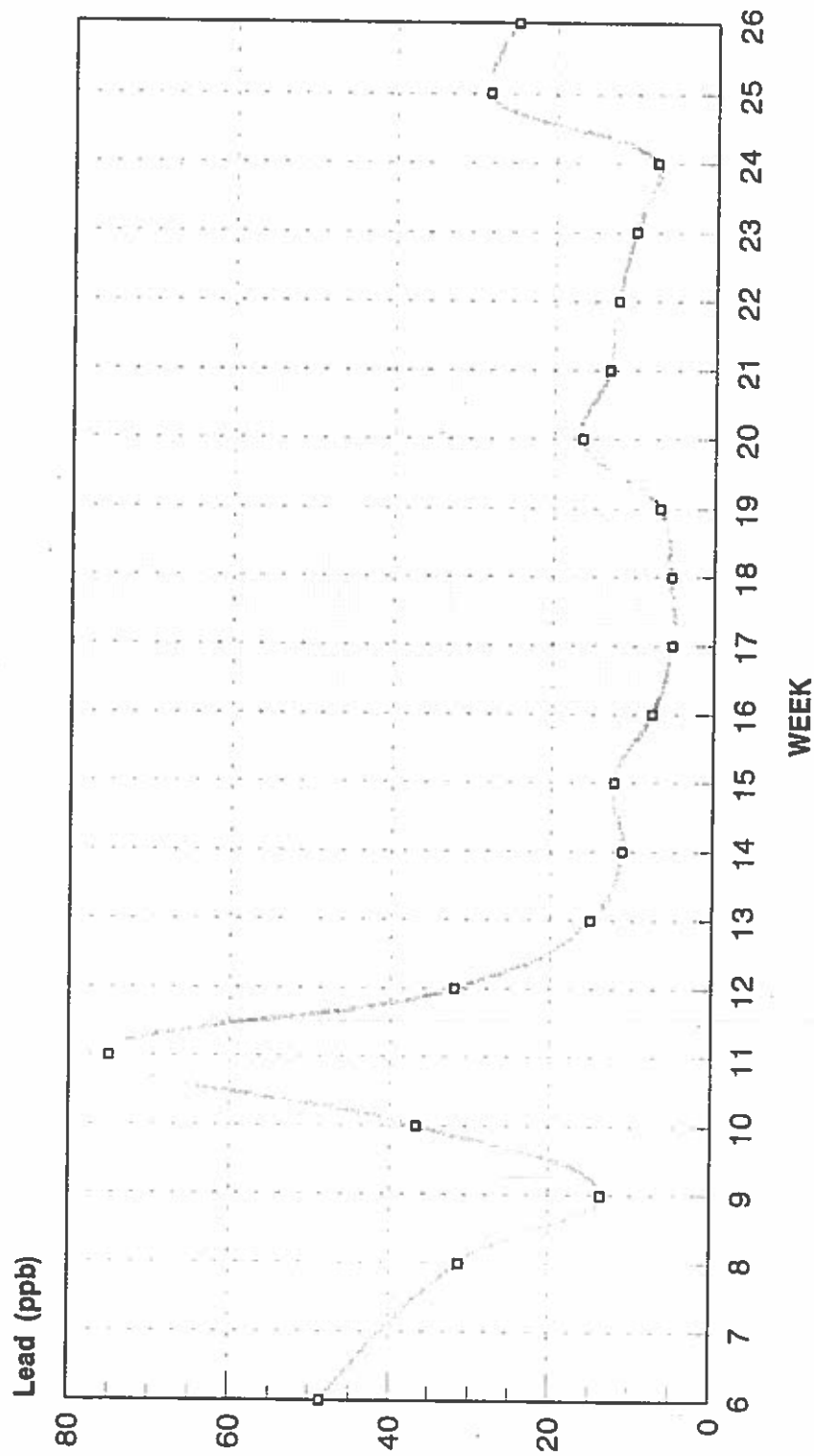


Figure 3.5

□ Loop I: Lead Results

Lead concentration in ppb vs. Weeks

Lead results from copper loop with lead solder treated with orthophosphate

Lead corrosion control study
Loop I: Copper pipe with lead solder joints
With Orthophosphate treatment

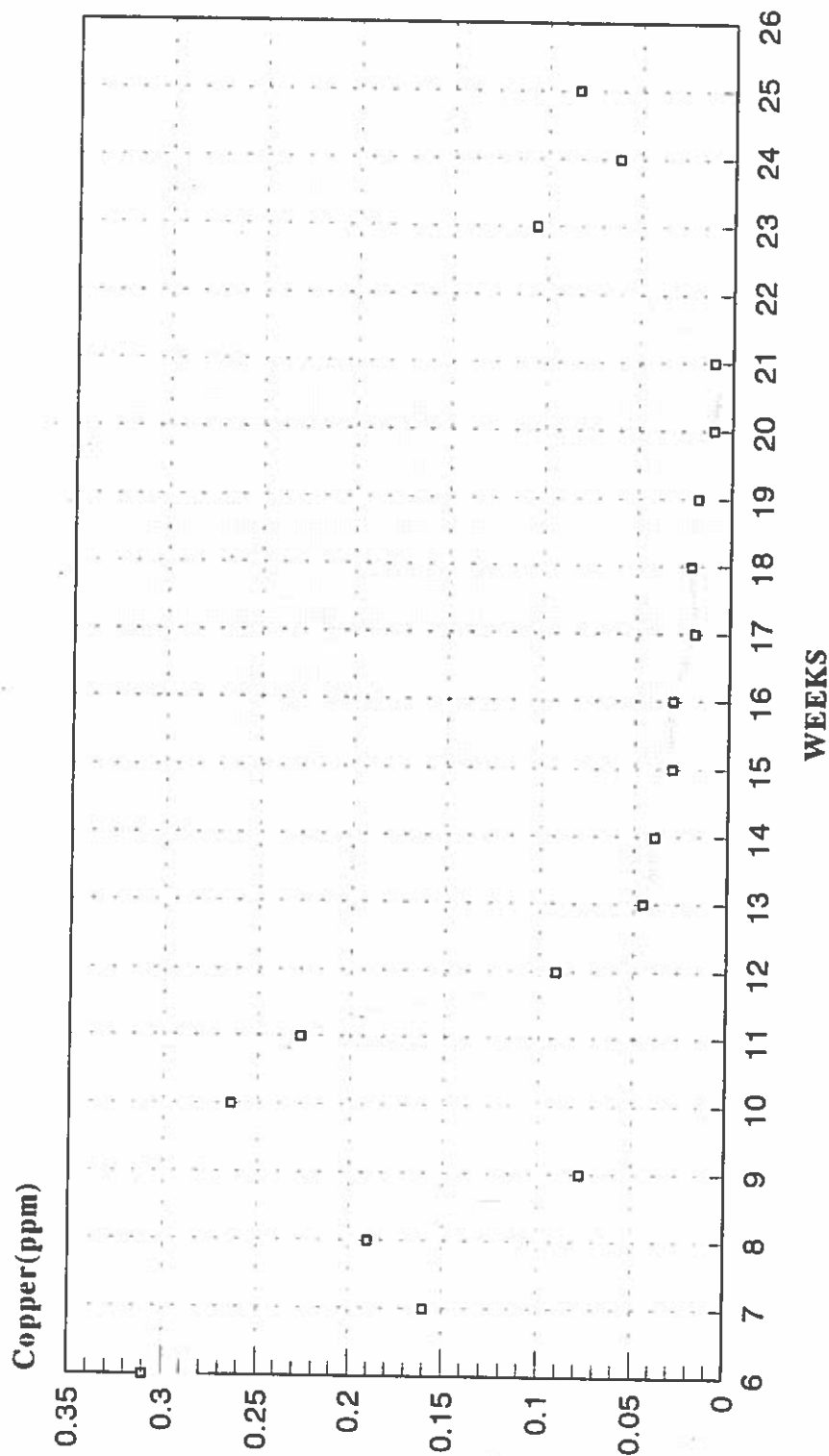


Figure 3.6

□ Loop I: Copper results

Copper concentration in ppm Vs. Weeks

Copper results from copper pipe with lead solder joints

Table 3.9
Pipe Loop II: Loop with Lead pipe
With orthophosphatetreatment

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>
6	437.0		1
7	1232.0		1
8	-		1
9	1125.0		1
10	657.0		1
11	1290.0		1
12	248.0		1
13	848.0		1
14	508.0		1
15	92.0		1
16	216.0		1
17	145.0		1
18	99.0		1
19	70.0		1
20	-		1
21	64.0		1
22	102.0		1
23	135.0		1
24	202.0		1
25	233.0		1
26	210.0		None

Corrosion control study
Loop II: Lead Pipe
 Lead results from lead pipe with orthophosphate treatment

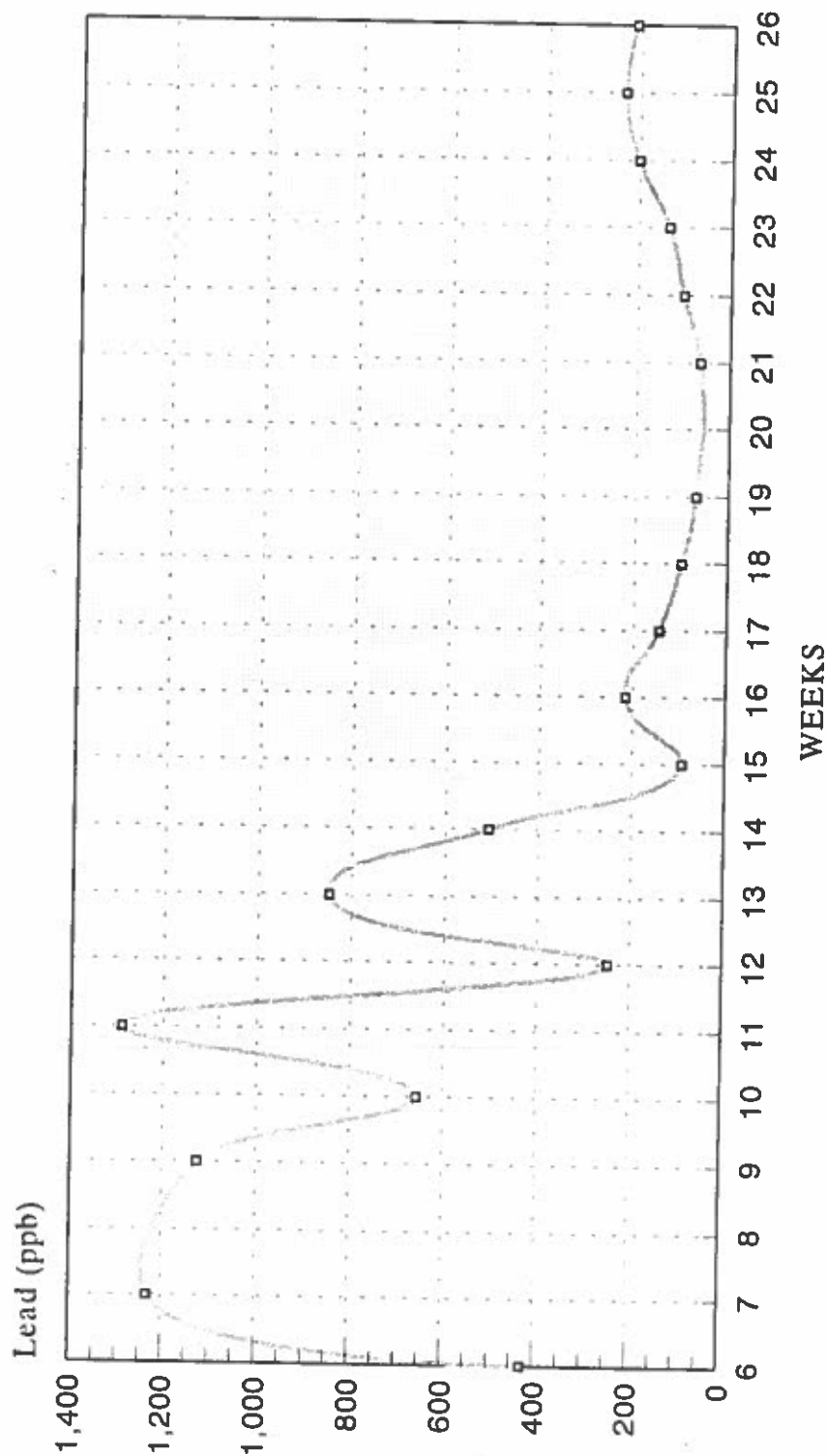


Figure 3.7

□ Loop II: Lead Results

Lead concentration in ppb Vs. Weeks
 Lead pipe with orthophosphate treatment

Table 3.10
Loop III: Copper pipe with Lead solder
With Silicate treatment

<i>Week#</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm) as Si</i>
6		0.31	None
7	85.3	0.25	24
8	25.6	0.19	24
9	18.5	0.031	24
10	11.4	0.044	18
11	17.0	0.0323	18
12	23.6	0.018	18
13	12.89	0.023	18
14	15.1	0.018	12
15	6.7	0.022	12
16		0.016	12
17	10.6	0.0175	12
18	4.7	0.04	12
19	10.1	0.026	12
20	-	0.02	12
21	5.0	0.01	12
22	5.0		9
23	6.4	0.019	9
24	-	0.014	9
25	6.5	0.027	9
26	5.6	0.013	9
27	6.8	0.015	9

<i>Week#</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm) as Si</i>
28	4.5	0.023	9
29	1.8	0.013	9
30	1.8	0.013	9
31	1.7	0.039	9
32	3.0	0.023	9
33	5.0	0.02	9
34	2.8	0.039	8
35	4.6	0.032	8
36	4.4	0.024	8
37	4.2	0.009	8
38	4.0	0.028	8
39	3.0	0.09	None

Following shows the graphical representation of the changes for above data

Lead corrosion control study
Loop III: Copper pipe with lead solder and with Silicate treatment
Lead results from copper pipe with lead solder joints and with Silicate treatment

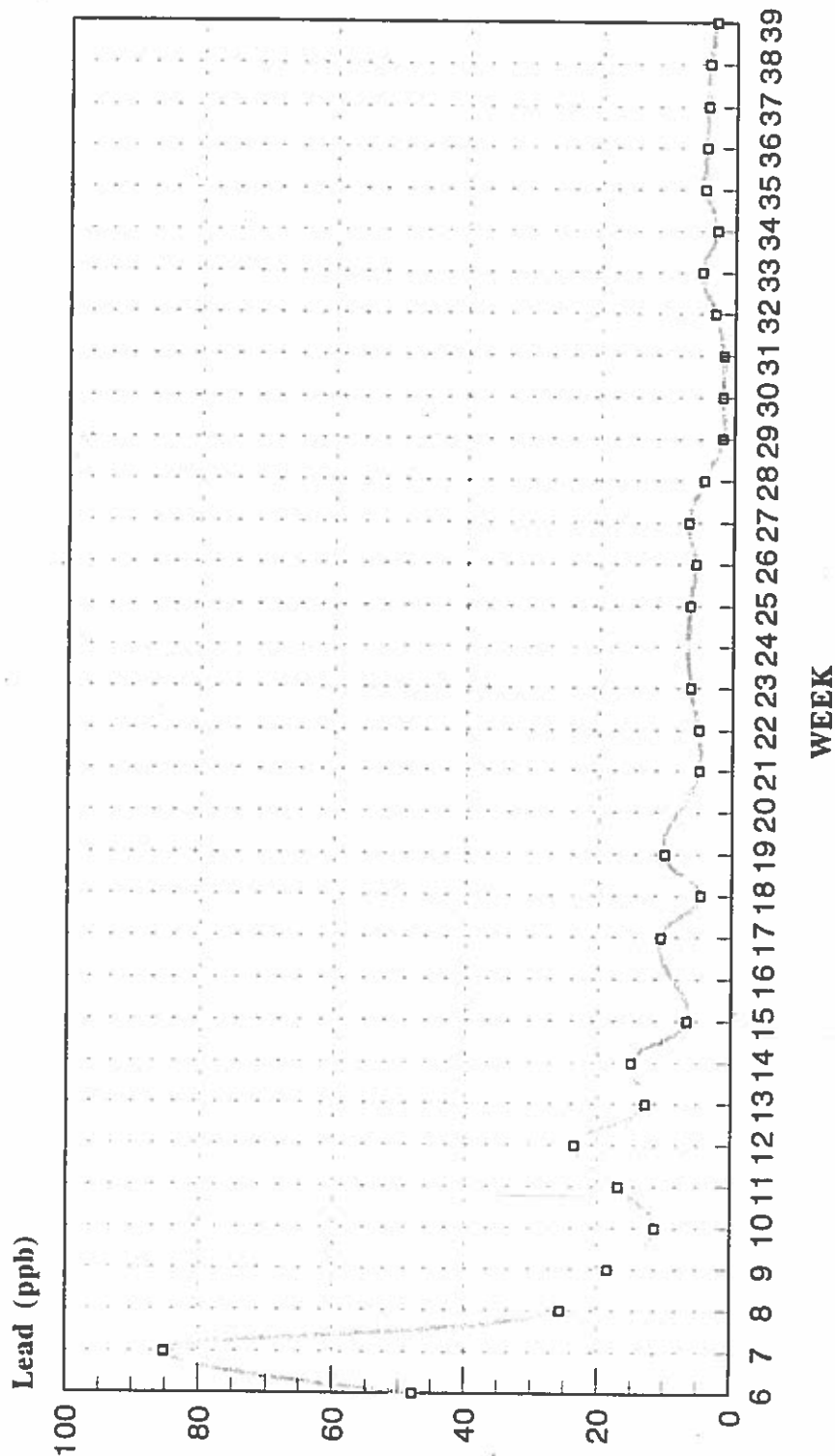


Figure 3.8
 □ Loop III: Lead Results

Lead concentration in ppb Vs. Weeks
 Lead results from loop III treated with Sodium silicate

Corrosion control study
 Loop III: Copper pipe with lead solder and with Silicate treatment
 With Sodium Silicate treatment

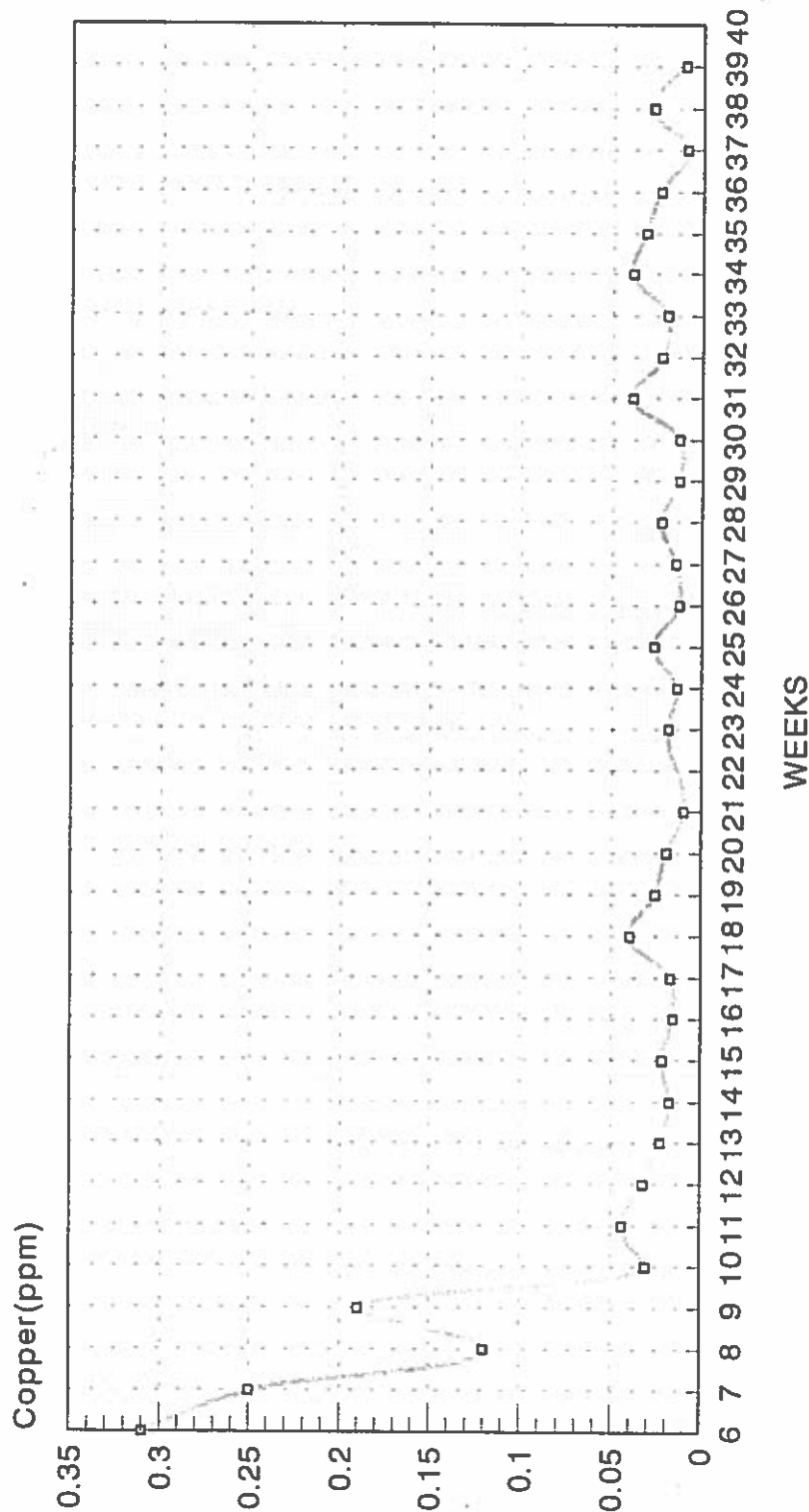


Figure 3.9

□ Loop III: Copper Result

Copper Results in ppm Vs. Weeks
 Copper pipe with Sodium Silicate as inhibitor

Table 3.11
Loop IV : Lead pipe loop
With Sodium Silicate treatment

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>
6	428.5		None
7	351.2		24
8	320.1		24
9	210.5		24
10	151.2		24
11	240.1		18
12	195.0		18
13	232.0		18
14	234.0		12
15	207.0		12
16	255.0		12
17	217.0		12
18	206.0		12
19	150.0		12
20	46.6		12
21	168.0		12
22	120.0		9
23	129.0		9
24	92.0		9
25	103.0		9
26	94.0		9
27	73.0		9

<i>Week #</i>	<i>Lead (ppb)</i>	<i>Copper (ppm)</i>	<i>Chemical Dosage (ppm)</i>
28	82.0		9
29	74.0		9
30	54.0		9
31	50.0		9
32	80.0		9
33	61.0		9
34	101.0		8
35	113.0		8
36	73.0		8
37	63.0		8
38	60.0		8
39	55.5		None
40	48.5		None

Please see the following graph

Corrosion control study
 Loop IV: Lead Pipe
 With Sodium Silicate treatment

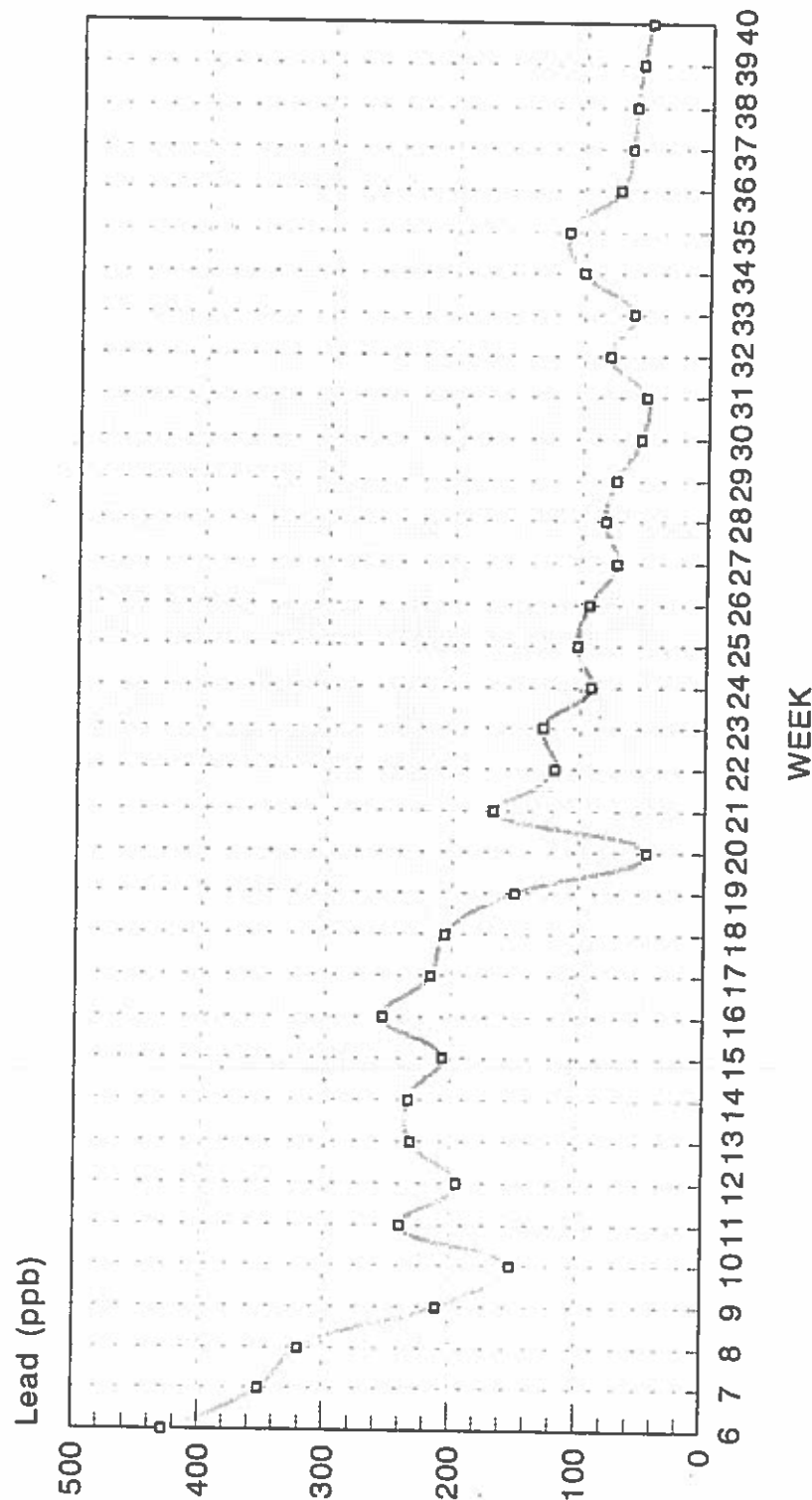


Figure 3.10

□ Loop IV: Lead Results

Lead concentration in ppb Vs. Weeks
 Lead results from Sodium Silicate treated lead pipe

Table 3.12
Loop V: Copper pipe with lead solder
Control loop (no treatment)

Week #	Lead (ppm)	Copper (ppm)	Chemical Dosage (Control Loop)
6	48.0	0.35	None
7	32.1	0.25	None
8	42.1	0.193	None
9	20.5	0.082	None
10	43.0	0.127	None
11	42.6	0.15	None
12	56.6	0.136	None
13	-	0.168	None
14	32.8	0.095	None
15	30.8	0.23	None
16	22.0	0.09	None
17	22.5	0.088	None
18	22.0	0.05	None
19	-	0.05	None
20	-	0.11	None
21	21.6	0.08	None
22	-	0.14	None
23	17.5	0.12	None
24	40.0	0.128	None
25	23.4	0.106	None
26	51.0	0.052	None
27	35.2	0.0577	None

Week #	Lead (ppm)	Copper (ppm)	Chemical Dosage (Control Loop)
28	18.0	0.064	None
29	15.1	0.168	None
30	15.1		None
31	38.4	0.045	None
32	34.5	0.05	None
33	104.7	0.129	None
34	24.1	0.125	None
36	29.1	0.06	None
37	52.1	0.07	None
38	24.6	0.07	None
39	24.6	0.08	None
40	24.0	0.08	None

The lead and copper concentration during the above period is shown in the following graphs

Corrosion control study
 Loop V: Copper pipe with lead solder
 With no treatment (Control loop)

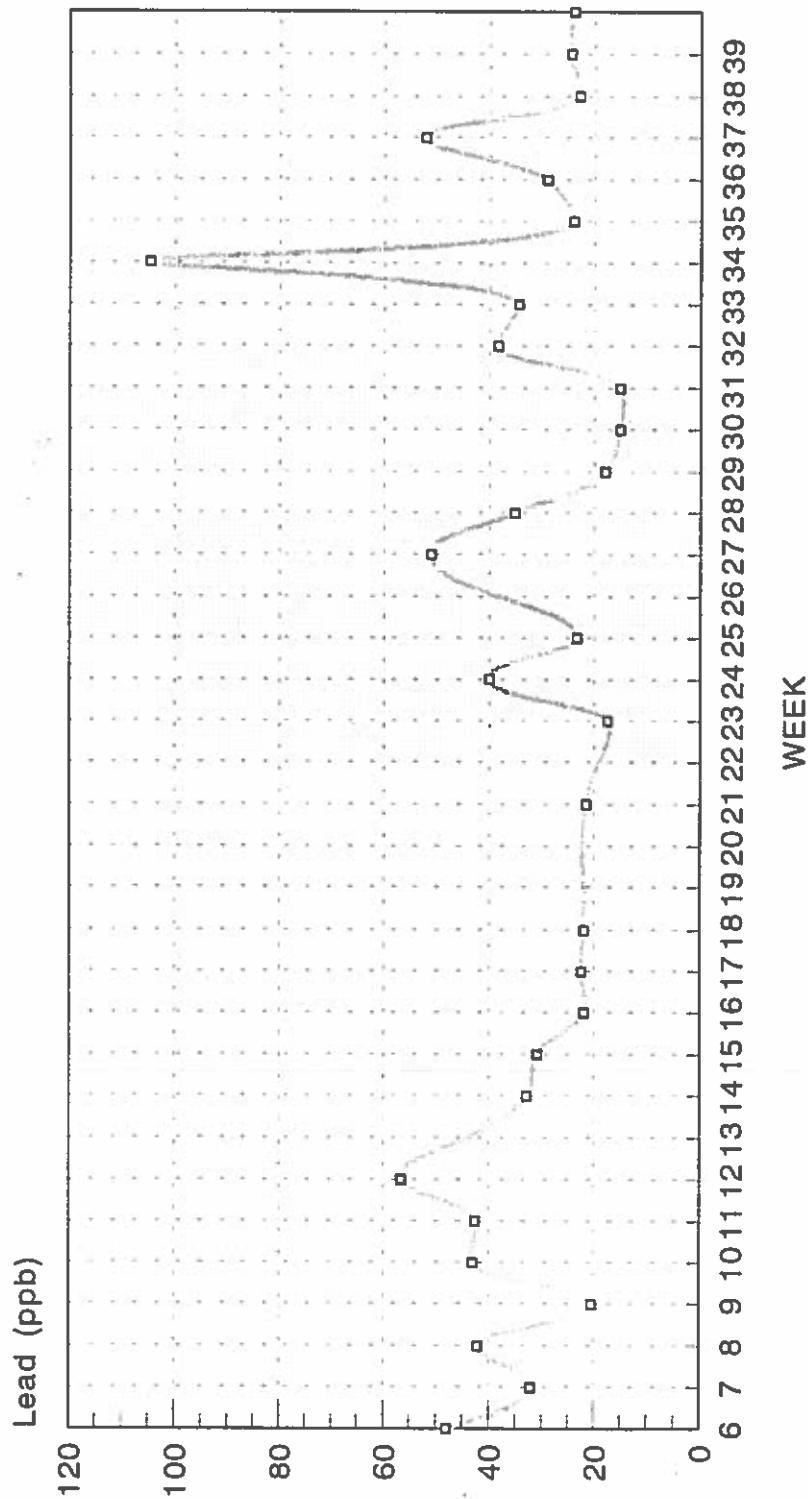


Figure 3.11

□ Loop V: Lead Results

Lead results in ppb Vs. Weeks
 Lead results from copper pipe with no treatment

Corrosion control study
Loop V: Copper pipe with lead solder and no treatment
Control loop with no treatment

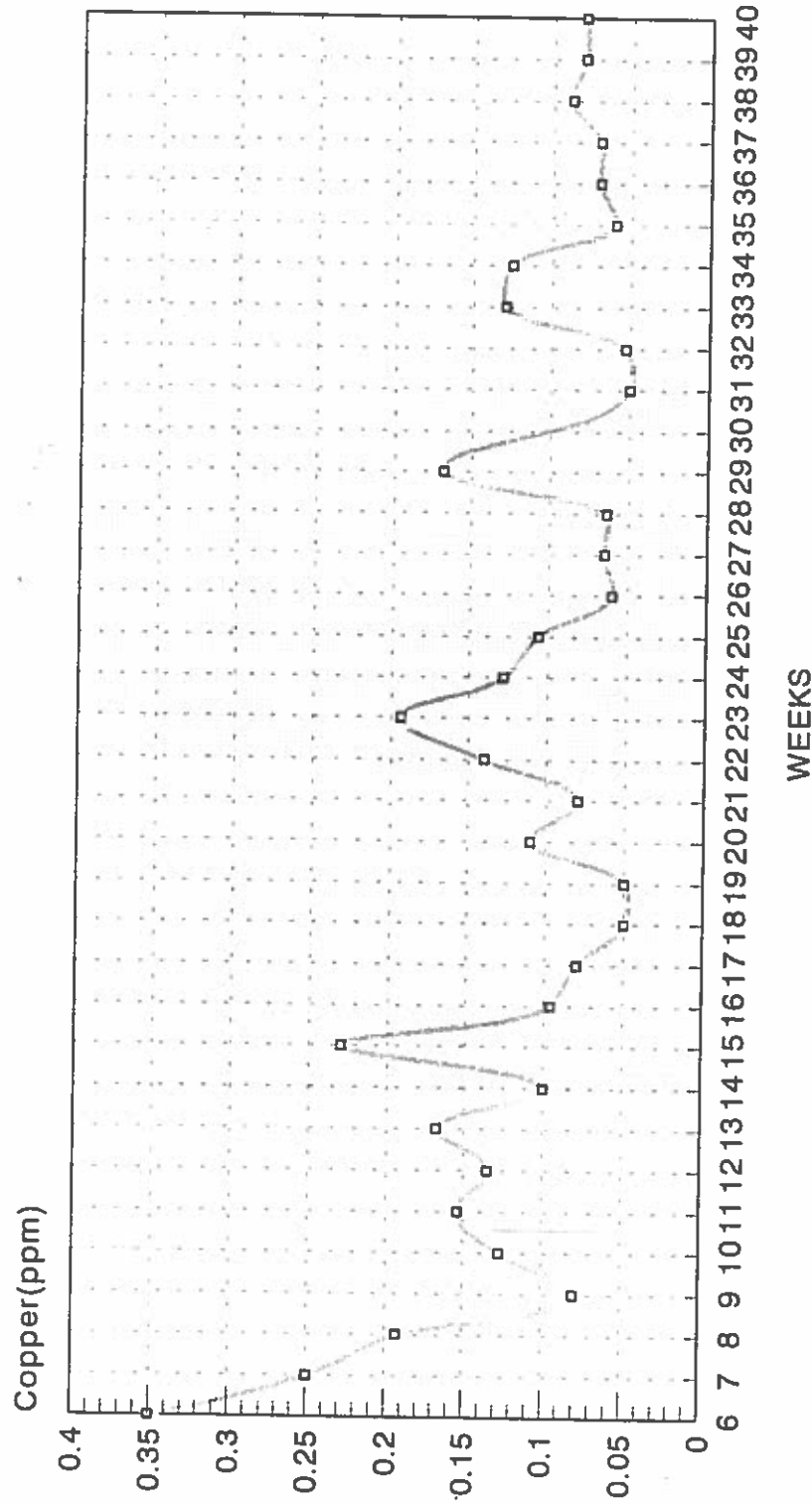


Figure 3.12

□ Loop V: Copper results

Copper in ppm Vs. Weeks
Control loop

Table 3.13
Loop VI: Lead Pipe
Control loop (no treatment)

Week #	Lead (ppm)	Copper (ppm)	Chemical Dosage (Control Loop)
6	430.0		None
7	390.5		None
8	410.1		None
9	366.0		None
10	350.9		None
11	370.0		None
12	440.0		None
13	371.0		None
14	254.0		None
15	-		None
16	264.0		None
17	490.0		None
18	249.0		None
19	209.0		None
20	476.0		None
21	240.0		None
22	297.0		None
23	458.0		None
24	308.0		None
25	258.0		None
26	247.0		None
27	284.0		None

Week #	Lead (ppm)	Copper (ppm)	Chemical Dosage (Control Loop)
28	280.0		None
29	284.0		None
30	230.0		None
31	258.0		None
32	218.5		None
33	248.0		None
34	346.0		None
36	353.0		None
37	-		None
38	-		None
39	283.0		None
40	251.0		None

Please see the following graphs

Corrosion control study
 Loop VI: Lead Pipe
 Control loop with no treatment

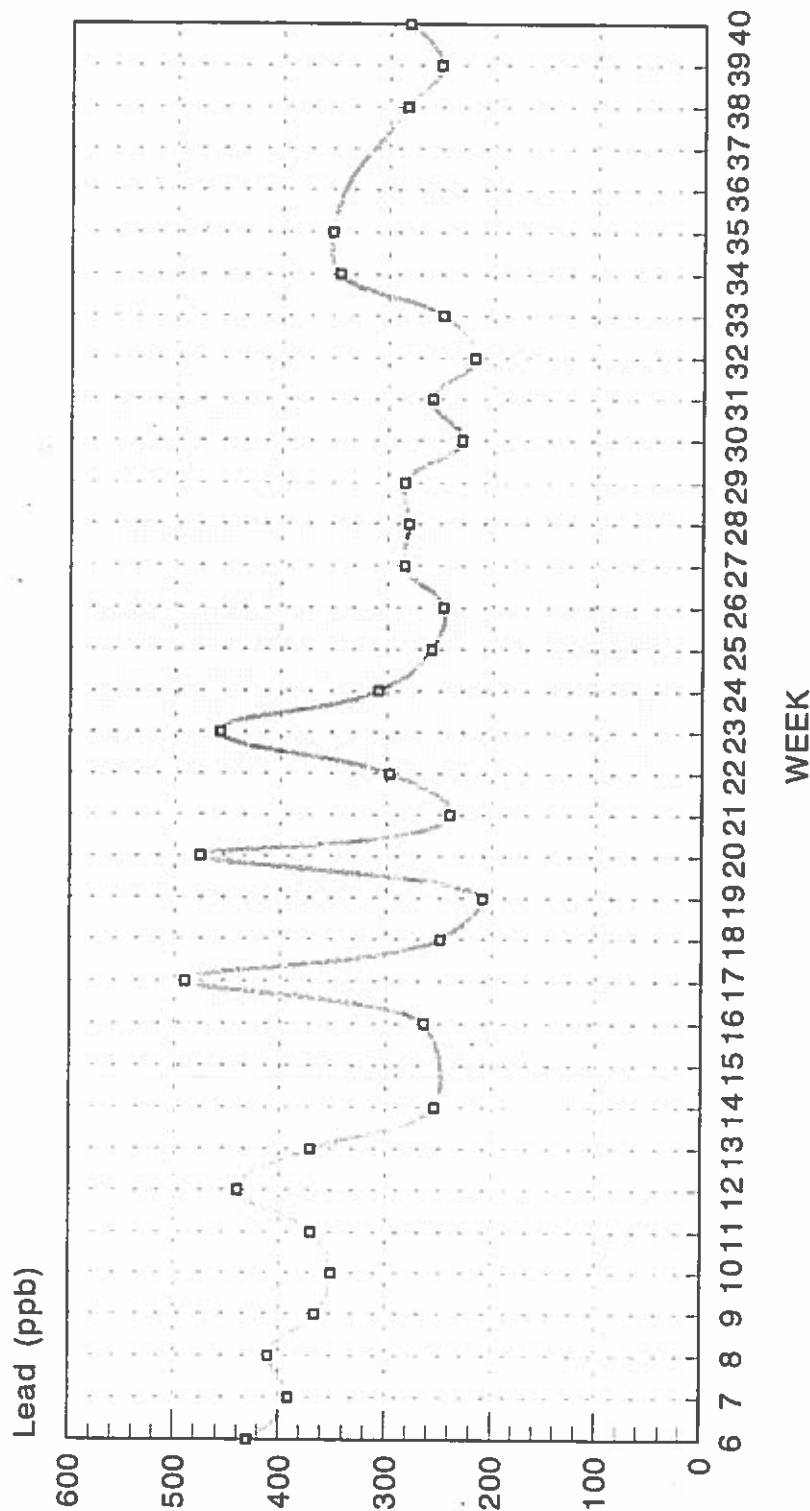


Figure 3.13

Loop VI: Lead Results

Lead in ppb Vs. Weeks
 Control loop

Corrosion optimization study
Lead results from Copper pipes with lead solder
Lead results

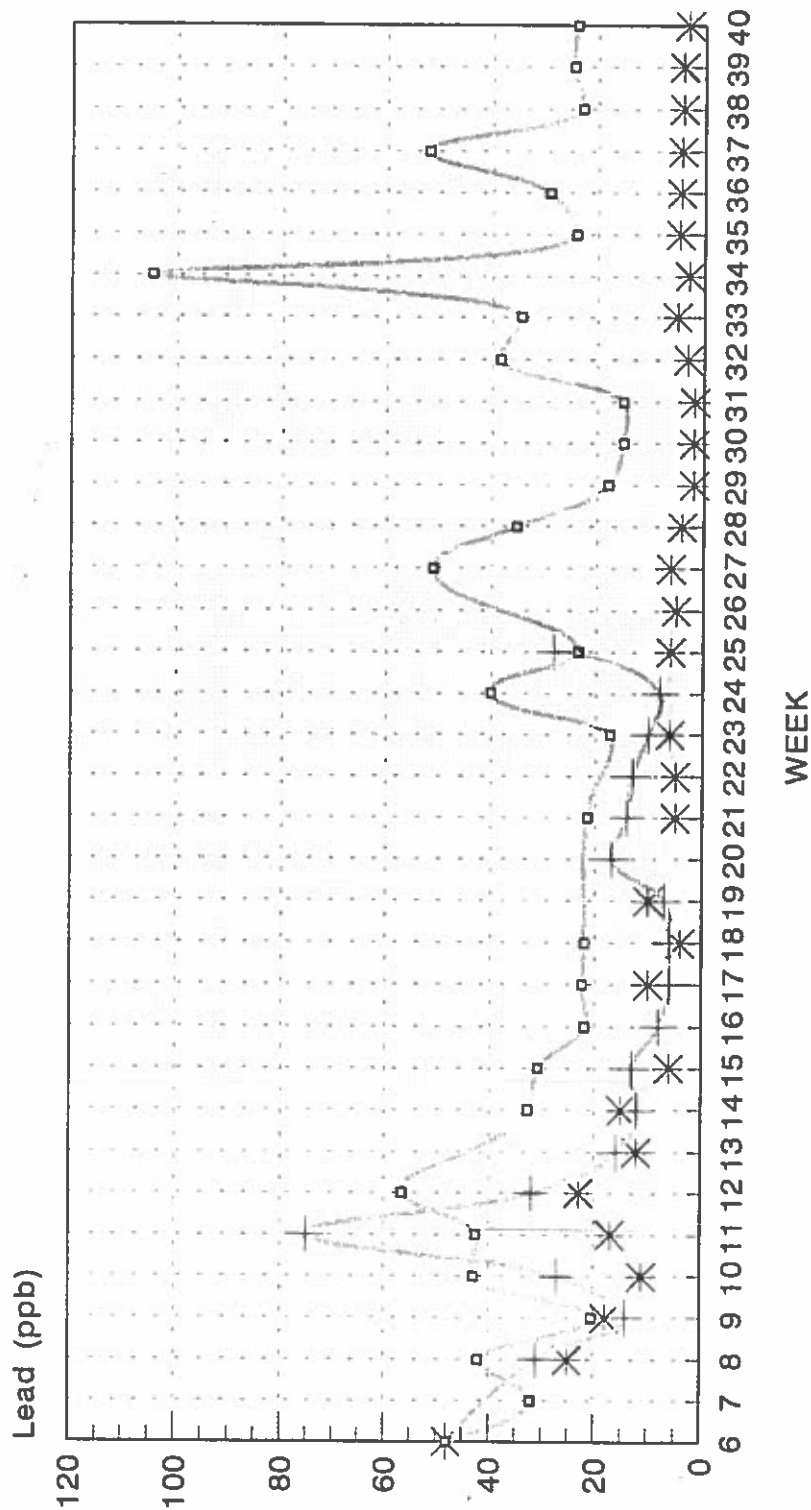


Figure 3.14
□ Loop V:Control + Loop I:orthophosphate * Loop III:silicate

Comparison of lead results in two treatment loops and control
Lead in ppb Vs. Weeks

Corrosion optimization study
Copper pipe with lead solder
Copper results

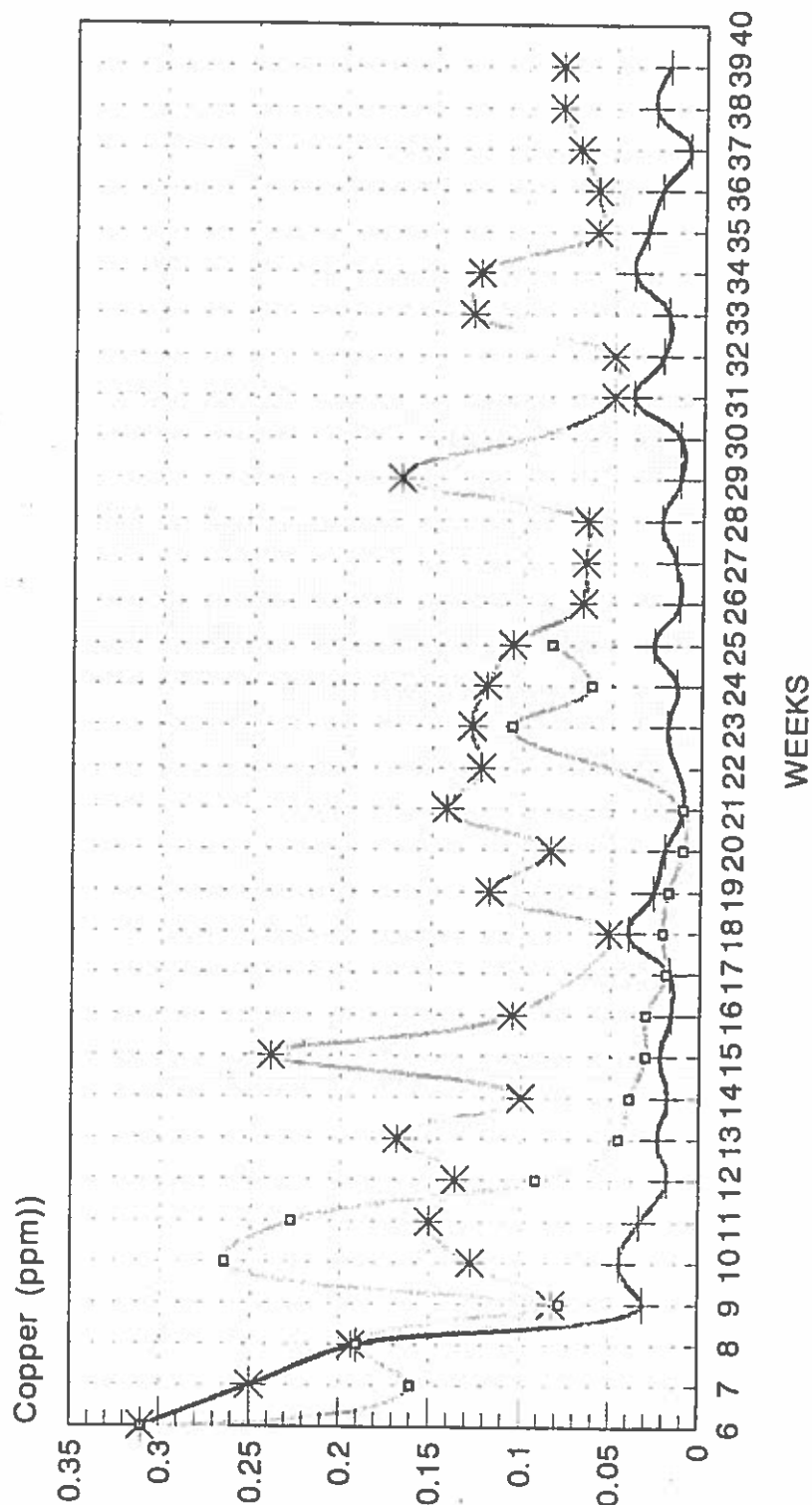
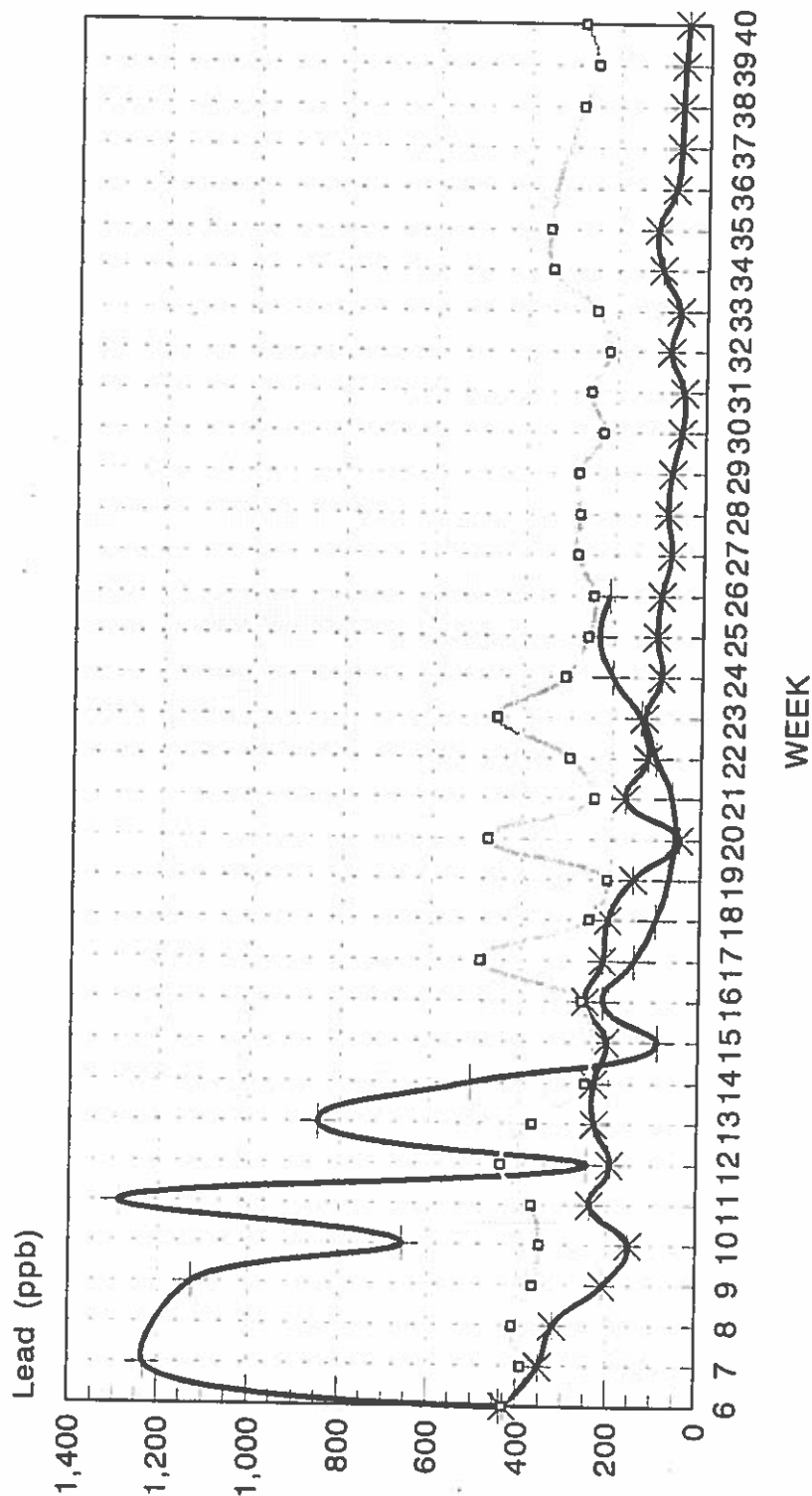


Figure 3.15
Comparison of copper results in two treatment loops and control
Copper in ppm Vs. Weeks
□ Loop I: Orthophosphate + Loop II: Silicate * Loop IV: Control

Corrosion optimization study
Lead pipes loops
Lead results



3.16

Comparison chart with both treatment and control loop results
Lead in ppb Vs. Weeks

□ Loop VI: Control loop + Loop II: Orthophospha. * Loop IV: Silicate loop

3.9 Final treatment period

After the 26th week, loop I & II orthophosphate testing was completed and the loop was cleaned and raw water was run through it until the 30th week. This was done to regenerate the initial condition and to free the loop for testing another chemical. During this time, all the results were monitored and once it started giving similar results as the control loop, a ortho-poly blended phosphate was added to the loop at a rate of 1 ppm (as ortho).

The results from that testing is tabulated in the following table.

Table 3.14
Loop I: Copper pipe with lead solder
With Ortho-Poly blended phosphate

Week #	Lead (ppb)	Copper (ppm)	Chemical Dosage ppm as ortho
26	35.5	0.02	None
27	45.0	0.061	None
28	32.4	0.10	None
29	35.0	0.08	None
30	14.5	0.15	1
31	12.5	0.09	1
32	10.9	0.085	1
33	9.6	0.045	1
34	8.8	0.03	1
35	24.5	0.019	1
36	7.5	0.029	1
37	6.5	0.035	1
38	6.0	0.04	1

Week #	Lead (ppb)	Copper (ppm)	Chemical Dosage ppm as ortho
39	5.8	0.035	1
40	12.3	0.03	1
41	5.2	0.025	1
42	6.8	0.03	1

Table 3.15
Loop II: Lead
With Ortho-Poly blended phosphate

Week #	Lead (ppb)	Copper (ppm)	Chemical Dosage ppm as ortho
26			None
27	158.5		None
28	220.0		None
29	285.5		None
30	235.0		1
31	250.0		1
32	145.5		1
33	130.0		1
34	210.0		1
35	120.0		1
36	98.5		1
37	75.0		1
38	66.3		1
39	108.5		1
40	98.5		1

Week #	Lead (ppb)	Copper (ppm)	Chemical Dosage ppm as ortho
41	66.3		1
42	58.5		1

Table 3.16
 Loop V: Copper pipe with lead solder
Control loop (no treatment)

Week #	Lead (ppm)	Copper (ppm)	Chemical Dosage (Control Loop)
26	51.0	0.052	None
27	35.2	0.0577	None
28	18.0	0.064	None
29	15.1	0.168	None
30	15.1		None
31	38.4	0.045	None
32	34.5	0.05	None
33	104.7	0.129	None
34	24.1	0.125	None
36	29.1	0.06	None
37	52.1	0.07	None
38	24.6	0.07	None
39	24.6	0.08	None
40	24.0	0.08	None

Table 3.17
Loop VI: Lead Pipe
Control loop (no treatment)

Week #	Lead (ppm)	Copper (ppm)	Chemical Dosage (Control Loop)
26	247.0		None
27	284.0		None
28	280.0		None
29	284.0		None
30	230.0		None
31	258.0		None
32	218.5		None
33	248.0		None
34	346.0		None
36	353.0		None
37	-		None
38	-		None
39	283.0		None
40	251.0		None

The following pages shows the variation graphically.

Corrosion optimization study
Lead results from loop I and loop V
Blended phosphate loop Vs. Control loop

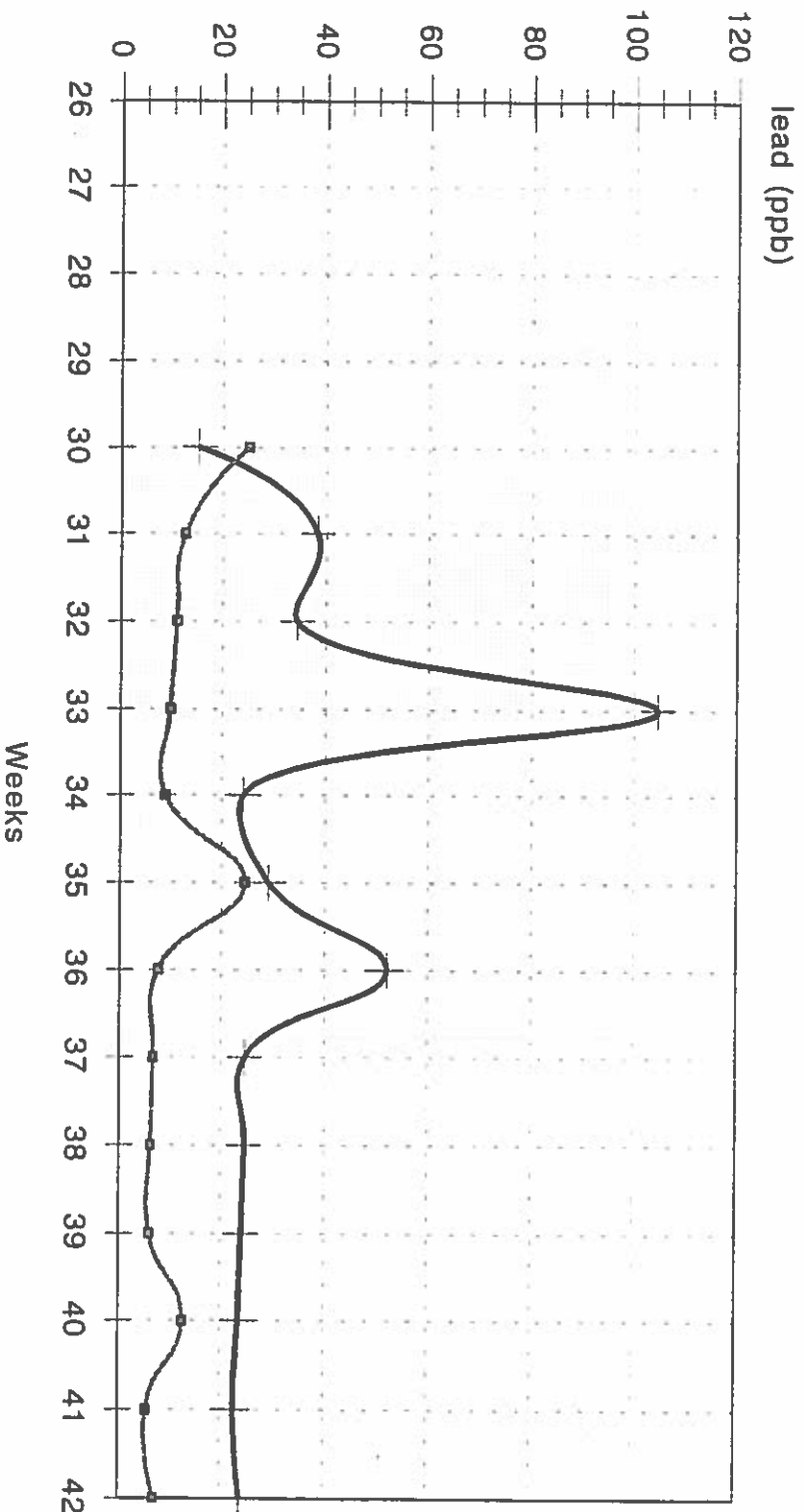


Figure 3.17

□ Loop I: Blended phosp. + Loop V: Control

Loop I is fed with blended phosphate and loop V is control
Copper pipe loops with lead solder joints

Corrosion optimization study
Copper results from loop I and loop IV
Blended phosphate loop Vs. Control loop

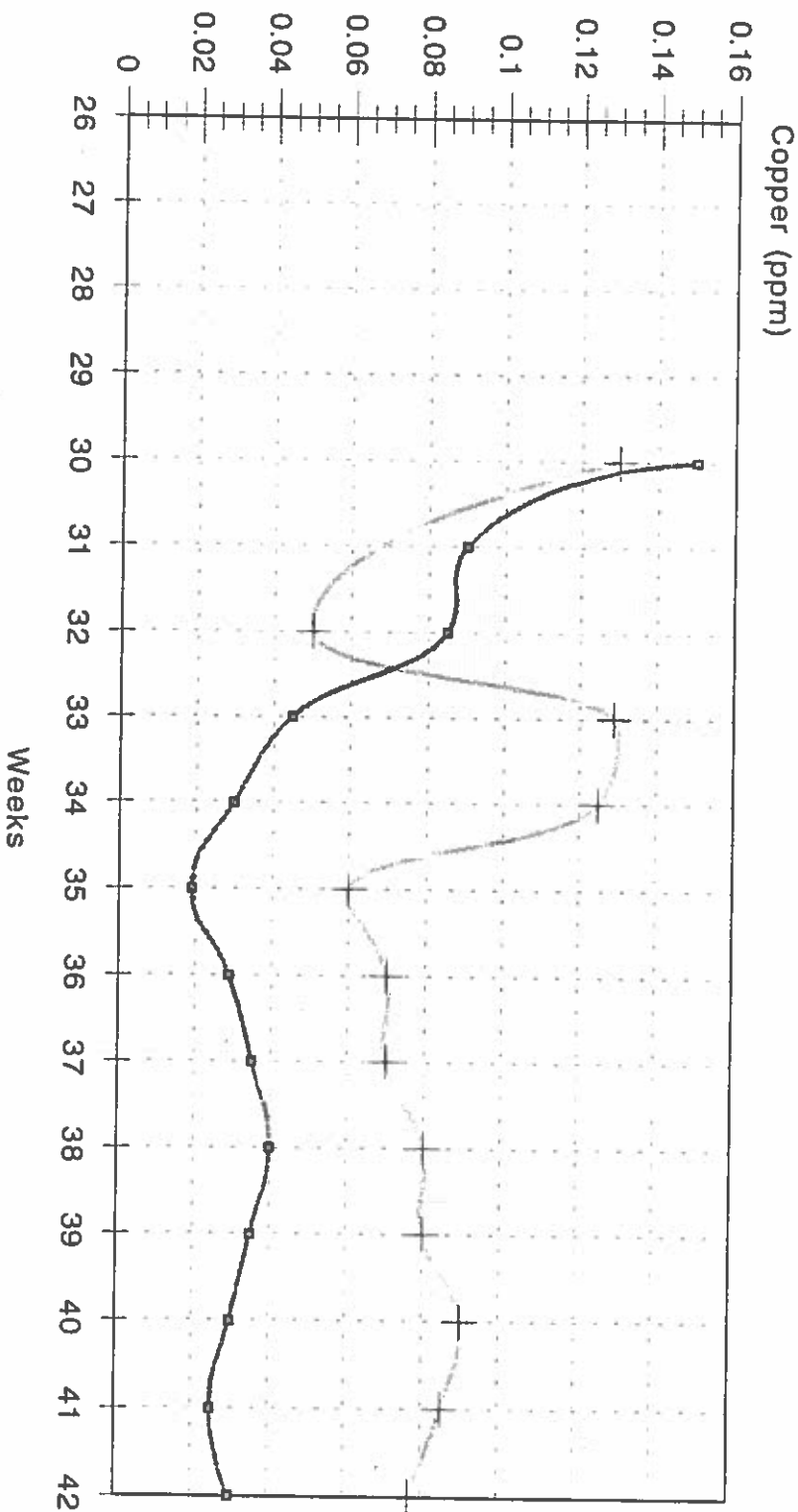


Figure 3.18

Loop I: Blended phosphate Loop V: Control

Loop I is fed with blended phosphate and loop V is control
Copper results from copper loop with lead solder

Corrosion optimization study
Lead results from loop II and loop VI (lead pipes)
Blended phosphate Vs. Control

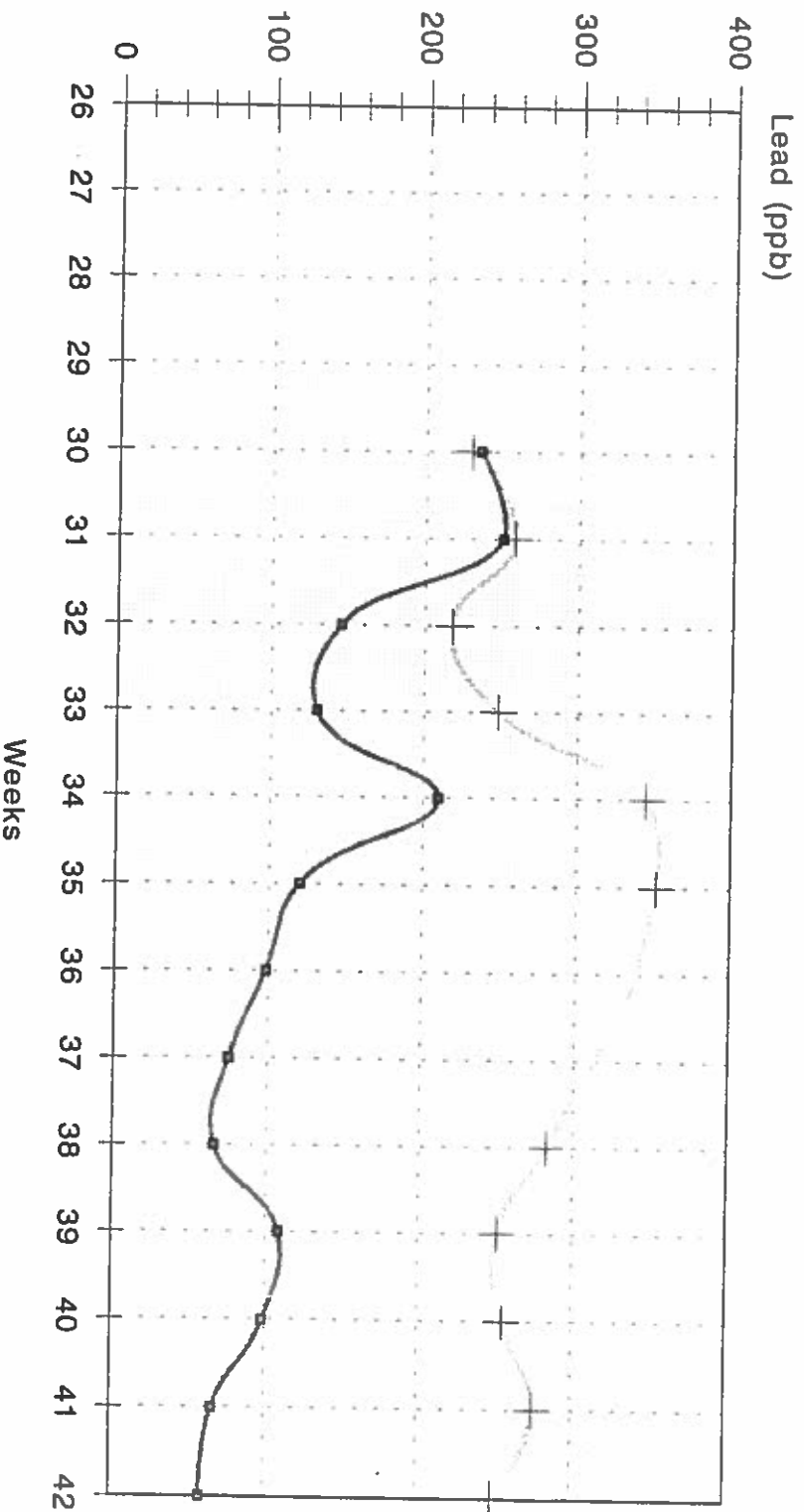


Figure 3.19

—■— Loop II: Blended phos. + Loop VI: Control

Loop II is fed with blended phosphate and loop VI is control
Lead results from lead pipe

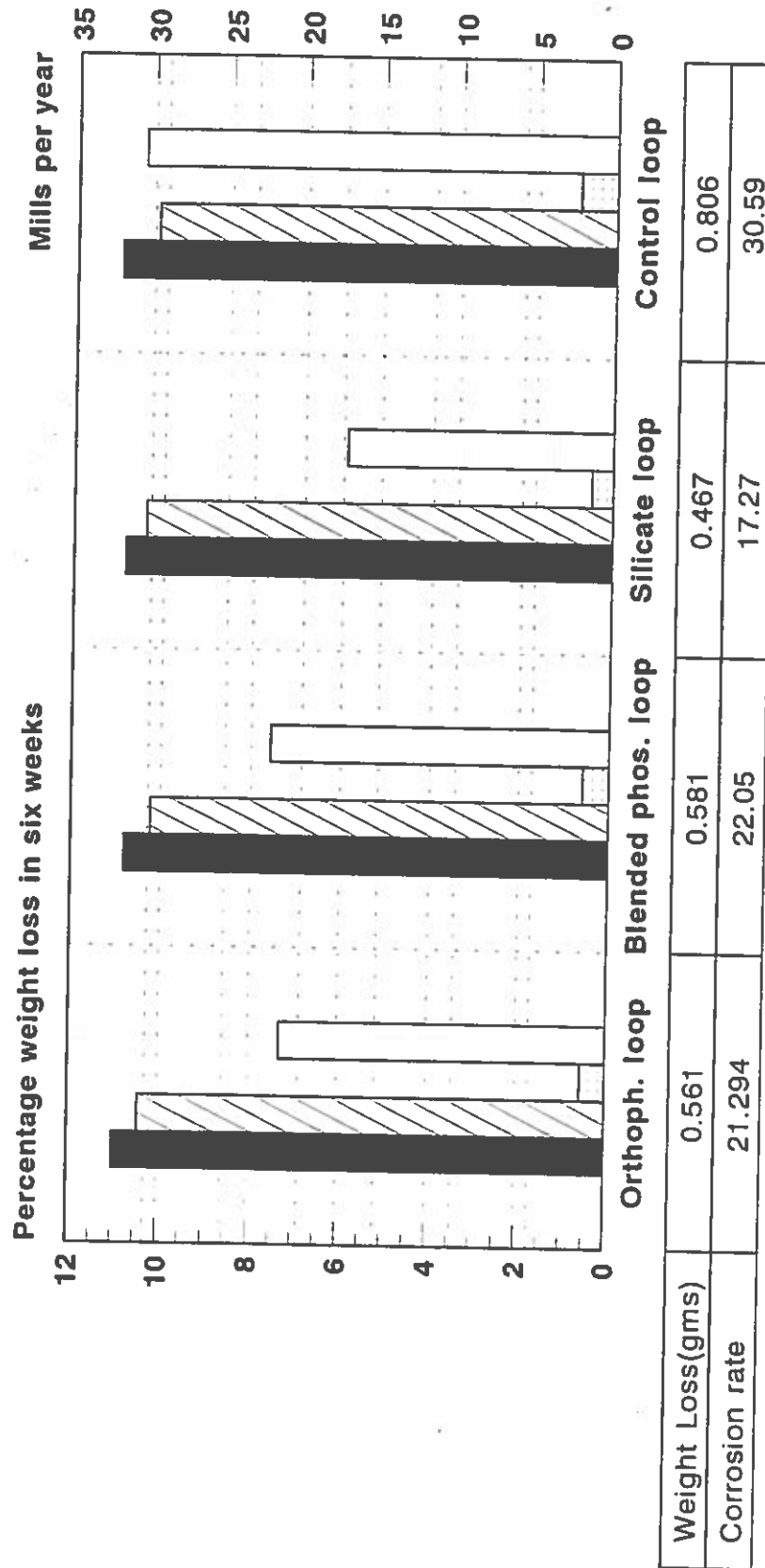
Table 3.17a
Pipe insert (coupon) results

Location	Weight loss (gms)	Days	Corrosion rate (MPY)
Orthophosphate loop	0.561	49	21.29
Blended phosphate loop	0.595	49	22.58
Silicate loop	0.467	49	17.72
Control loop	0.806	49	30.595

Table 3.18
**Average chemical feed rates and water quality characteristics by
treatment alternatives for the pilot testing.**

Treatment alternative	Water quality Characteristics mg/l			Chemical feed rate
	Ca Hardness	Alkalinity	pH	
Orthophosphate	37.0	31.0	7.4	1 ppm (ortho)
Blended phosphate	37.0	31.0	7.4	1 ppm (ortho)
Silicate	37.0	31.0	8.4	12 ppm

**Lead corrosion control study
Pipe insert (coupons) Results
Comparison of coupon weight loss & Corrosion rates**



Figure

Initial Wt.(gms)
 Final Wt.(gms)
 Weight Loss(gms)
 Corrosion rate

Initial Stabilization Period (with no treatment)

4.0 COMPARISON OF ALTERNATIVES

4.0 COMPARISON OF ALTERNATIVES

4.1 Assessment of orthophosphate treatment:

Bench scale studies and the pilot plant studies showed that orthophosphate is effective effective in reducing lead corrosion from lead pipes and copper pipes with lead solder joints. However, addition of an orthophosphate in the Pequannock Water Treatment Plant is not desirable due to the potential for severe algal growth in the Cedar Grove open reservoir. If the City decides to feed this inhibitor after the reservoir, the City may need to build a number of satellite feeding stations which may involve substantial capital improvement and, hence, create a liability to the City's financial implication. Also, the City has reservation about using any phosphate in the system because of prior experience with a phosphate and the subsequent dirty water complaints that followed.

4.2 Assessment of Blended Phosphate:

Blended phosphate showed a lesser reduction of corrosion than the orthophosphate. Similar to orthophosphate, it also cannot be added at our Pequannock treatment plant. This product costs more than the orthophosphate, and to get the same ortho dosage more chemical will have to be added.

4.3 Assessment of Silicate:

Both bench scale and pilot plant studies showed that silicate is an effective corrosion inhibitor. Addition of silicate increases the pH of the water and, hence, the present lime dosage can be reduced. Another advantage is that silicate can be used at the treatment plant directly without building additional satellite feeding stations. The advantage of feeding at the treatment plant allows for better control over the chemical dosage. Silicates are also effective in controlling the condition of red water.

Algal (diatoms) growth in open reservoirs is usually associated with the presence of silica. Silica is an essential nutrient for diatoms, which are a type of algae. The ultimate effect of higher silica concentrations from silicates is not well understood. Both silica and phosphate are a must for the diatoms to grow. So an increase in silica will not increase the growth of diatoms because the other nutrient,

phosphate, will be the controlling factor.

When water containing silica is heated in high pressure boilers, some silica vaporizes. Power generating utilities, in particular, and other industries use high pressure boilers to produce steam that is used to operate turbines. Silica vapors in the steam can condense onto turbine blades and cause permanent damage to the blades. There is a recommendation from the American Society of Mechanical Engineers (ASME) on the limit of silica concentration in water used in high pressure boilers. ASME recommends a limit of 20 mg/l silica concentration for boilers operating under high pressure (751-900 psi). Silica dosage reduction is not necessary, especially in the absence of condensing turbines. The silica dosage in the loop tested varied from 24 ppm to 8 ppm. The higher dosage of silica is required only in the early stage of the chemical treatment.

4.4 Overall assessment

Lead in lead pipe:

Throughout the test period sodium silicate produced the most consistent reduction in lead concentration. Over the term of the project lead concentrations were reduced by 65% with sodium silicate. This was slightly better than the orthophosphate treatment which reduced the lead concentration by about 60%. The lead reduction from orthophosphate treatment was inconsistent and the lead levels actually went up during the initial treatment period. Another notable phenomena was that in the orthophosphate and blended phosphate treatment loops, the mild steel pipe inserts pitted worse than the silicate loops and the water samples drawn from the loops were dirty and brownish. This evidence supports our earlier experience of phosphates and its aggressiveness. During the coldest months, lead leaching decreased in the control loop and there was only a slight reduction of lead leaching in all of the treatment loops. With the return of warmer water temperatures, the lead concentrations again increased in the control loops.

Lead in copper pipe with lead solder:

In this case, also, the most consistent results were obtained from the silicate loops, which produced almost a 60% lead reduction.

Copper in copper pipes with lead solder:

Copper results from copper pipe with lead solder is compared on the graph. It can be seen that all treatment chemicals achieved similar reductions of copper concentrations, well below that of the control loop and below the action level of 1.3 mg/l. Silicate produced a slightly lower concentration than the rest of the chemicals.

pH Variation:

Addition of sodium silicate in the silicate loop increased the pH in that loop. With a chemical dosage of 24 mg/l, the pH was 9.0 and with a chemical dosage of 8 mg/l the pH was 8.4. Minimal changes were noted in the ortho and blended phosphate loops.

4.5 Preliminary cost estimates

Unit capital cost and operational & maintenance costs associated with the several corrosion control alternatives are typically very similar. The key cost difference is attributable to the cost of the chemical and the dosage. As described earlier, the chemical cost for a blended phosphate would be more than for an orthophosphate. The blended phosphate showed a lesser lead reduction than the orthophosphate.

Table 4.1
Estimate of probable costs

Chemical	Chemical Cost \$/Year	Capital Cost ¹ (\$)	Capital Cost (\$/Year)	Total Annual Cost (\$)
Blended phosphate ³	750,000	2,500,000	250,000	1,000,000
Orthophosphate ³	450,00	2,500,00	250,000	700,000
Silicate	750,000	400,000 ²	40,000	790,000

¹ Capital cost has been amortized over 20 years with an interest rate of 8%.

² The capital cost in this case is reduced because the Pequannock Treatment Plant is already equipped with the necessary corrosion inhibition feeding systems, including the storage tanks and pumps. Only minor alteration is required.

³ Orthophosphate and blended phosphate is deleterious to the operation of the Cedar Grove open balancing reservoir.

4.5 Performance comparison**Table 4.2****Corrosion Control Treatment Performance
Ranking Matrix**

Treatment Alternative	Performance Criteria		
	Metal Solubility		Weight Loss
	Lead	Copper	Mild Steel
Weighing factors	.8	.2	1
Orthophosphate	5	7	5
Blended phosphate	3	5	3
Silicate	7	7	7
Control	0	0	3
Interim performance Score			
Orthophosphate	4.0	1.4	5
Blended phosphate	2.4	1.0	3
Silicate	5.6	1.4	7
Control	0.0	0.0	3
Measurement techniques	0.7	0.7	0.3
Weighing factor			
Measurement scores			
Orthophosphate	2.8	0.98	1.5
Blended phosphate	1.68	0.7	0.9
Silicate	3.92	0.98	2.1
Control	0	0	0.9
Total Score			
Orthophosphate	5.28		
Blended phosphate	3.28		
Silicate	7.0		
Control	0.9		

4.6 Final Corrosion Control Treatment Selection Matrix

The factors selected to choose the best corrosion control chemical (inhibitor) are as follows:

1. **Performance:** Performance of alternative treatment techniques were evaluated for mitigating corrosion, based on the prioritization of (a) targeted material (b) measurement technique (c) confidence in testing program results. This was given the prime importance in the selection criteria.
2. **Feasibility & Reliability:** Feasibility of implementing corrosion control treatment and the reliability of alternative treatment approach based on treated water quality and full scale operational characteristics.
3. **Costs :** Costs associated with the installation and operation, where alternate treatment have comparable performance.

A decision matrix including each of the above factors was developed (shown below) and applied as the basis for the selection of optimum corrosion control treatment.

Table 4.3
Selection Matrix

Treatment Alternative	Corrosion control performance	Treatment reliability	Estimated costs	Total
Weighing factors	0.6	0.3	0.1	1
Orthophosphate	5	5	5	5.0
Blended phosphate	3	3	3	3.0
Silicate	7	7	0	6.3
Existing/Control	0	5	7	0.7

5.0 CONCLUSION

CONCLUSION

The objective of the study was to determine which of the possible corrosion control techniques would most effectively reduce lead and copper concentrations in the household service piping and plumbing. Even though the initial Lead and Copper Rule compliance monitoring results from Newark exceeded the lead action level, the compliance problem does not necessarily indicate an inadequate current corrosion control program. The study proved corrosion control studies of this nature are useful for comparing the effectiveness of the available various chemical treatments in reducing corrosion, but cannot predict how effective the treatment will be in meeting the lead and copper action levels in the distribution system. The following conclusions were reached:

In lead pipes, Sodium Silicate treatment produced slightly better and more consistent results than orthophosphate. Blended phosphate produced the poorest results. Sodium silicate can be used centrally at the treatment plant and eliminate the requirement for satellite feeding stations.

In copper pipes with lead solder joints, both orthophosphate and silicate produce a similar reduction level in lead. Orthophosphate increased the lead concentration during the initial stages of the treatment and showed inconsistent results. The silicate produced a more consistent reduction of lead than the orthophosphate.

In copper pipe with lead soldered joints, the copper concentration were reduced by all three different treatment options. Orthophosphate developed a dirty water problem in the pipe loop because of its aggressiveness towards the mild steel coupons.

Sodium silicate costs more than orthophosphate or blended phosphate. The total expense for sodium silicate treatment will be more than the other treatment options.

5.1 Recommendation

The City of Newark, after an extensive corrosion optimization study, recommends that sodium silicate be added at the Pequannock Treatment Plant to produce the optimal corrosion control treatment. The initial silicate dosage would be around 18 mg/l to 20 mg/l during the passivation period and this would be brought down to 8 mg/after the passivation period.

REFERENCES

1. Lead and Copper Rule Guidance Manual, Vol. I, By EPA.
2. Lead and Copper Rule Guidance Manual, Vol II, By EPA.
3. Lead control strategies, AWWA Research foundation.
4. Pipe loop testing at the Lowell water treatment plant by Leonard J. Mackoul, P.E..
5. Evaluation of Corrosion control Alternatives, By Bruce Johnson, Journal, NEWWA March '93.
6. PQ Soluble Silicates, Bulletin 37-3, By PQ Corporation.
7. Statistical procedures for corrosion studies, USEPA.
8. Sodium Silicate for the simultaneous control of lead, copper and iron based corrosion, By Jonathan C. Clement, Wright Pierce Engineers
9. Optimizing treatment plant performance while implementing corrosion control, By Bernard Rousseau, Pennick Water Works.
10. The effectiveness of bicarbonate/pH process as treatment for corrosion control, By Judith Ann Judge, Fitchburg Water Department.

Exhibit B



State of New Jersey

Christine Todd Whitman
Governor

Department of Environmental Protection
Water Supply Element
CN 426
Trenton, New Jersey 08625-0426
Tel# 609-292-7219
Fax# 609-292-1654

Robert C. Shinn, Jr.
Commissioner

August 8, 1995

Daniel Berardinelli, Manager
Newark Division of Sewers and Water Supply
1294 McBride Avenue
Little Falls New Jersey 07424

Dear Mr. Berardinelli:

Re: Newark Division of Sewers and Water Supply
PWS-ID No.: 0714001
Project # CCS-93-001
Corrosion Control Plan for City of Newark

The Bureau of Safe Drinking Water (Bureau) has received and reviewed correspondence from the City of Newark dated 16 June 1995, 22 June 1995 and 13 July 1995 regarding the City's plans for providing effective corrosion control for both its Pequannock and Wanaque sources of water supply. The purpose of this letter is twofold: first, to approve the City's corrosion control study on the Pequannock supply, and set up a schedule for follow-up monitoring and setting of optimal water quality parameters; and second, to clarify the Bureau's position regarding the treatment to be provided on the Wanaque supply.

PEQUANNOCK SUPPLY:

Bureau staff has reviewed the report dated 30 June 1994 entitled "City of Newark - Report on Corrosion Optimization Study". The Bureau agrees with the study's finding that a silicate-based inhibitor is the preferred corrosion control inhibitor at the Pequannock Water Treatment Plant (WTP). Therefore, the Bureau hereby approves the Newark Division of Sewers and Water Supply's corrosion control study. What follows is the timetable for implementation and testing of the approved corrosion control alternative. Given the six-month delay in the Bureau's response to the corrosion studies, all of the deadlines in the scheduled have been extended by six months.

1. Today - Bureau approves corrosion control study. An application should be filed with the Bureau as soon as possible for the installation of sodium silicate feed equipment at the Pequannock WTP.
2. 1 July 1997 - All corrosion control treatment should be installed and certified as operational by a Professional Engineer.
3. 31 December 1997 (or six months after treatment has been certified to the Bureau as installed)- first follow-up monitoring period ends. Sampling should be performed as follows and the results submitted to the Bureau:
 - a. Lead and Copper Analysis Input Forms (enclosed) including results from samples taken from at least one hundred (100) taps, as in the initial monitoring period. These samples should be taken once during each monitoring period. A reasonable effort should be made to obtain samples from the same locations as in the initial monitoring period.
 - b. Water Quality Parameters Analysis Input Forms (enclosed) including results from:
 - i) samples taken at representative distribution system sites. These samples should be taken from two (2) taps twice each monitoring period and should include the following parameters: pH, alkalinity and corrosion inhibitor residual.
 - ii) samples taken at the points of entry. These samples should be taken biweekly and include pH, alkalinity and corrosion inhibitor feed rate.

Be sure to distinguish between point of entry (P) and distribution system (D) under Sample Type. Also, please provide the location and facility ID number for each point of entry. Facility ID numbers should correspond to those given in the enclosed Source File Listing for your system. Please advise the Bureau of any discrepancies in the Source File Listing.
3. 30 June 1998 (or twelve months after treatment has been certified to the Bureau as installed) - second follow-up monitoring period ends. Results from the period and a recommendation for optimal corrosion control treatment including ranges for optimal water quality parameters (pH, alkalinity and distribution system silicate residual) should be submitted to the Bureau within 30 days of the end of the monitoring period.
4. 1 September 1998- Bureau reviews optimal corrosion control treatment recommendation and approves and/or designates the final water quality parameter ranges. These ranges will become part of Newark's general monitoring requirements.

WANAQUE SUPPLY:

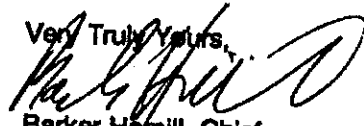
On 15 June 1995, the Bureau approved the corrosion control optimization study for the North Jersey District Water Supply Commission (NJDWSC). This study, prepared by Malcolm Pirnie Inc. and based upon pipe loop testing at the F.A. Orechio treatment plant, concluded that the addition of a non-zinc orthophosphate was the most effective form of corrosion control for water from the Wanaque Reservoir. As per Bureau policy, any of NJDWSC's client systems that wish to adopt this method of corrosion control need merely to inform the Bureau of their intentions - no further study would be required, unless a system mixed Wanaque water with its own source.

Any system that proposes to utilize a different form of corrosion control assumes the burden of proof to show that its desired treatment will be as effective in reducing lead leaching by its source water (in this case Wanaque Reservoir water) as the orthophosphate feed. To date, the Bureau has seen no evidence that silicate feed can meet this standard on the Wanaque supply. On the contrary, the NJDWSC study seemed to indicate that silicate had no effect (or negligible effects) on the lead levels in the study's samples. In addition, such system would be responsible for maintaining the appropriate water quality parameters (WQP's) in their correct range once its proposed corrosion control treatment was approved and follow-up monitoring completed.

Should Newark wish to continue to pursue a silicate feed system for its Wanaque supply, they must first show the Bureau results from their own study performed on Wanaque water. This study should be initiated as soon as possible, and results submitted to the Bureau no later than 31 December 1995. Please note that this study period will not result in the extension of the 1 July 1997 deadline for installation of the corrosion control treatment for all the City's water supplies. The study should follow the procedures and sampling outlined in the EPA's "Lead and Copper Rule Guidance Manual."

Please indicate to the Bureau by 31 August 1995 whether the City intends to perform its own demonstration study on the Wanaque supply (to be completed by 31 December 1995) or will accept the results from the NJDWSC study. Should you have any questions regarding this matter, please contact Mark A. Hubal of the Bureau at (609) 292-5550.

Very Truly Yours,



Barker Hamill, Chief
Bureau of Safe Drinking Water

c: Jerry Notte, North Jersey District Water Supply Commission
Metro Bureau of Water and Hazardous Waste Enforcement
Vincent Monaco, BSDW

Exhibit C



WATER SUPPLY

JUN 19 1995

State of New Jersey

Christine Todd Whitman, Governor
OFFICE OF THE Department of Environmental Protection

Robert C. Shinn, Jr.
Commissioner

WATER SUPPLY ELEMENT
CN 426

TRENTON, NEW JERSEY 08625-0426
TEL. # 609-292-7219
FAX. # 609-292-1654

JUN 15 1995

Mr. Jerry J. Notte
North Jersey District Water Supply Commission
1 F. A. Orechio Drive
Wanaque, New Jersey 07465

Dear Mr. Notte:

Re: North Jersey District Water Supply Commission
PWS-ID No.: 1613001
Project # CCS-94-005
Corrosion Control Study for Wanaque Water Treatment Plant

The Bureau of Safe Drinking Water has reviewed the report entitled "Corrosion Control Study - Phase 2 Demonstration Testing" for the North Jersey District Water Supply Commission (NJDWSC) dated April 1995. The Bureau agrees with the report's conclusion that a non-zinc orthophosphate seems to be the preferred alternative for control of lead levels in NJDWSC's Wanaque supply.

Please note that this approval is for the results of the corrosion control study only. It is incumbent upon each water purveyor receiving Wanaque water to contact the Bureau with its own corrosion control recommendations. This recommendation may be as simple as a letter indicating the purveyor's acceptance of NJDWSC's study results. Any purveyor who does not intend to accept the study's findings must submit their own recommendations to the Bureau, as does any purveyor who blends Wanaque water with another surface or groundwater source. The deadline date for medium-sized (3,300 - 50,000 customers) to submit their recommendations is 1 July 1995. Large-sized (>50,000) systems were required to submit by 1 July 1994, but the Bureau will extend the deadline to match the medium-sized systems. Any purveyor who has not submitted a recommendation by 1 July may be considered in violation of the Lead & Copper Rule (LCR), and the Bureau reserves the right to take appropriate action at that time.

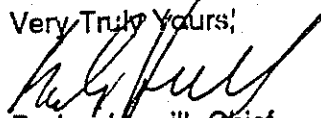
The LCR requires that for large systems, the preferred corrosion control alternative be installed by 1 January 1997. The Bureau intends to enforce this date with NJDWSC, even though some of the systems served are medium-sized. Being that NJDWSC serves no retail water customers, no schedule of follow-up monitoring is included in this approval. Each purveyor will receive a schedule for follow-up monitoring upon receipt of its corrosion control recommendation. The Bureau has no problem if NJDWSC wishes to perform follow-up monitoring for these systems, as long as all applicable requirements of the LCR are met; but again, ultimate responsibility for tap and distribution monitoring rests with the individual purveyors. NJDWSC will ultimately be responsible for maintaining finished water quality and for complying with optimal water quality

parameters (WQP's) once they are approved by the State, assuming that the corrosion control implementation is performed by and is under the direct control of the Commission.

As discussed at the meeting of participants on 8 May 1995, the Bureau understands the concerns that some purveyors have with an additional form of treatment on their water. The Bureau does not believe there will be any adverse effects on water quality from orthophosphate addition, but will work closely with concerned systems to ensure that their customers are afforded adequately protected water with a minimum of disruption.

Should you have any questions regarding this matter, please contact Mark A. Hubal of the Bureau at (609) 292-5550.

Very Truly Yours,



Barker Hamill, Chief
Bureau of Safe Drinking Water

c: Northern Region of Water and Hazardous Waste Enforcement
Alan Dillon, BSDW
Brian Keune, BSDW
Vincent Monaco, BSDW
Distribution List (attached)

HUBAL\NJD3:ck

Exhibit D

PEQUANNOCK WTP
CORROSION CONTROL
REVIEW AND
RECOMMENDATIONS -
FINAL

City of Newark
Lead and Copper Rule Compliance Study
Newark, NJ

City of Newark Department of
Water and Sewer Utilities

March 15, 2019



Table of Contents

Section 1 Executive Summary	1-1
Historical Lead Concentrations.....	1-1
Scale Analysis.....	1-3
Sequential Sampling.....	1-4
Potential Causes of Recent Lead Exceedances.....	1-5
Recommendations	1-6
Section 2 Background	2-1
2.1 Current Corrosion Control Treatment (CCT).....	2-3
2.1.1 1994 Corrosion Optimization Study	2-4
2.1.2 Treatment Modifications Impacting Corrosion Control Since 1994.....	2-5
2.1.3 Current Corrosion Control Treatment.....	2-6
Pequannock Supply	2-6
Wanaque Supply.....	2-7
Recent CCT Optimization Efforts.....	2-7
2.2 Lead and Copper Rule Compliance Sampling Results.....	2-7
2.3 Lead Frequency Distribution.....	2-20
2.3.1 Lead Frequency Distribution – Pequannock Service Area	2-20
2.3.2 Lead Frequency Distribution – Wanaque Service Area.....	2-23
2.3.3 Pequannock Service Area Focus.....	2-25
Section 3 Historic Water Quality and Chemical Usage Data	3-1
3.1 Recent Water Quality Data	3-2
3.1.1 Chloride-to-Sulfate Mass Ratio.....	3-11
3.2 Chemical Usage Observations	3-12
3.3 Long-Term Water Quality Trends	3-16
3.3.1 Historic pH – Pequannock WTP and Valley Road Rechlorination Station.....	3-16
3.3.2 Historic Chlorine Residual – Valley Road Rechlorination Station.....	3-19
Section 4 Lead Sequential Sampling	4-1
4.1 Sequential Sampling Program Protocol	4-1
4.2 Results of Newark’s Initial Sequential Sampling.....	4-2
4.3 Discussion	4-7
Section 5 Pipe Scale Analysis.....	5-1
5.1 EPA Scale Analysis Testing and Results.....	5-1
5.2 EPA Elemental Analysis Testing and Results.....	5-5
43 Chancellor Avenue	5-6
80 Heckel Street.....	5-6
183 Highland Avenue.....	5-6
50 Goldsmith Avenue	5-7
674 5 th Street.....	5-7

5.3 Analysis of Results	5-8
5.3.1 Comparison of Sequential Sampling Results and Scale Analysis	5-8
5.3.2 Formation of Tetravalent Lead (Pb(IV)) Scales	5-8
5.3.3 Additional Scale Analyses	5-9
Section 6 Potential Causes of Elevated Lead Levels	6-1
6.1 Overview	6-1
6.2 Decrease in pH in the Distribution System	6-1
6.2.1 pH Impacts on Pb(II) Scales	6-2
6.2.2 pH Impacts on Pb(IV) Scales	6-2
6.2.3 Sodium Silicate and pH	6-4
6.3 LCR Compliance Sampling	6-4
6.3.1 First-Draw Sample Volume Required by the LCR	6-5
6.3.2 Error Resulting from Customer Collection of Samples	6-5
6.3.3 Accuracy of Inventory and Confirmation of Sample Sites	6-5
6.3.4 Proportional Mix of Pequannock and Wanaque Sampling Sites	6-5
Section 7 Desktop Corrosion Control Evaluation	7-1
7.1 Theoretical Lead Solubility Modeling	7-1
7.1.1 Calcium Hardness Adjustment	7-1
7.1.2 Alkalinity and pH Adjustment	7-1
7.1.3 Phosphate-based Corrosion Inhibitors	7-2
7.1.4 Silicate-based Corrosion Inhibitors	7-2
7.2 Theoretical Lead Solubility Modeling	7-3
7.3 Model Inputs	7-5
7.4 Lead Solubility – Existing Conditions	7-6
7.5 Lead Solubility – Modified CCT Alternatives	7-6
7.5.1 Increased Finished Water pH	7-6
7.5.2 Addition of Orthophosphate	7-7
7.5.3 Other Alternatives Not Considered	7-10
Section 8 Recommendations	8-1
8.1 Chemical and Orthophosphate Dosage	8-3
8.2 Chemical Feed Location Recommendations	8-4
8.3 Distribution System pH Recommendation	8-5
8.4 Demonstration Pipe Loop Study	8-6
8.5 Implementation Schedule	8-7
8.6 Monitoring During Implementation	8-7
8.6.1 Sequential Sampling – Before and During Implementation	8-8
8.7 Additional Recommendations	8-8
8.7.1 Short-Term Recommendations	8-8
8.7.2 Long-Term Recommendations	8-9
8.8 Impacts on Consecutive Systems	8-9
8.9 Recommendations Summary	8-10
Works Cited	8-1

List of Figures

Figure ES-1 – Pequannock Service Area – Lead Sampling Data Percentage Frequency Distribution	1-2
Figure ES-2 – Site A – South Ward Lead Profile – September 10, 2018	1-4
Figure ES-3 – Historic Pequannock WTP Delivered Water pH	1-6
Figure 2-1 – City of Newark, NJ System Overview	2-2
Figure 2-2 – Lead Levels in the City of Newark (1992)	2-9
Figure 2-3 – Lead Levels in the City of Newark (1998)	2-10
Figure 2-4 – Lead Levels in the City of Newark (2002)	2-11
Figure 2-5 – Lead Levels in the City of Newark (2003)	2-12
Figure 2-6 – Lead Levels in the City of Newark (2006)	2-13
Figure 2-7 – Lead Levels in the City of Newark (2009)	2-14
Figure 2-8 – Lead Levels in the City of Newark (2012)	2-15
Figure 2-9 – Lead Levels in the City of Newark (2015)	2-16
Figure 2-10 – Lead Levels in the City of Newark (January – June 2017)	2-17
Figure 2-11 – Lead Levels in the City of Newark (July – December 2017)	2-18
Figure 2-12 – Lead Levels in the City of Newark (January – June 2018)	2-19
Figure 3-1 – Historic Pequannock WTP Temperature – Influent and Delivered Water	3-5
Figure 3-2 – Historic Pequannock WTP Temperature – Influent Water Seasonal Trends	3-5
Figure 3-3 – Historic Pequannock WTP pH – Influent and Delivered Water	3-6
Figure 3-4 – Historic Pequannock WTP pH – Influent Water Seasonal Trends	3-6
Figure 3-5 – Historic Pequannock WTP Alkalinity – Influent and Delivered Water	3-7
Figure 3-6 – Historic Pequannock WTP Alkalinity – Influent Water Seasonal Trends	3-7
Figure 3-7 – Historic Pequannock WTP Calcium – Influent and Delivered Water	3-8
Figure 3-8 – Historic Pequannock WTP Calcium – Influent Water Seasonal Trends	3-8
Figure 3-9 – Historic Pequannock WTP Magnesium – Delivered Water	3-9
Figure 3-10 – Historic Pequannock WTP Magnesium – Delivered Water Seasonal Trends	3-9
Figure 3-11 – Historic Pequannock WTP Silica – Dose vs. Delivered Water	3-10
Figure 3-12 – Historic Pequannock WTP Chloride and Sulfate – Delivered Water	3-10
Figure 3-13 – Historic Pequannock WTP Chemical Dosages – Clarion, Lime, Sodium Silicate, PACl	3-13
Figure 3-14 – Historic Pequannock WTP Chemical Dosages – Clarion, Lime, Sodium Silicate, PACl - Seasonal Trends	3-13
Figure 3-15 – Historic Pequannock WTP Chemical Dosages – Sodium Hypochlorite	3-15
Figure 3-16 – Historic Pequannock WTP Chemical Dosages – Sodium Hypochlorite - Chlorine - Seasonal Trends	3-15
Figure 3-17 – Historic Pequannock WTP Delivered Water (System POE) pH	3-17
Figure 3-18 – Historic Valley Road Rechlorination Station pH (Distribution System POE) (2005 – 2018)	3-18
Figure 3-19 – Pequannock Gradient pH Values Across the Distribution System	3-19
Figure 3-20 – Historic Valley Road Rechlorination Station Post Chlorine Residual (Distribution System POE) (2005 – 2018)	3-20
Figure 4-1 – Map of Test Locations in Newark	4-3
Figure 4-2 – Site A – South Ward Lead Profile – September 10, 2018	4-5
Figure 4-3 – Site B – North Ward Lead Profile – September 11, 2018	4-6

Figure 5-1 – Lead Scale Images for Pipe Extracted from 43 Chancellor Avenue	5-2
Figure 5-2 – Lead Scale Images for Pipe Extracted from 80 Heckel Street	5-2
Figure 5-3 – Lead Scale Images for Pipe Extracted from 183 Highland Avenue.....	5-3
Figure 5-4 – Lead Scale Images for Pipe Extracted from 50 Goldsmith Avenue.....	5-3
Figure 5-5 – Lead Scale Images for Pipe Extracted from 674 5 th Street	5-3
Figure 6-1 – Potential-pH (Pourbaix) Diagram for Water with DIC = 8.5 mg C/L	6-3
Figure 7-1 – Effect of pH Adjustment on Theoretical Pb(II) Solubility	7-7
Figure 7-2 – Effect of Orthophosphate on Theoretical Pb(II) Solubility at Varying pH Values in Summer	7-8
Figure 7-3 – Buffer Intensity as a Function of Alkalinity and pH	7-10

List of Tables

Table ES-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data	1-2
Table ES-2 – Summary of CCT Recommendations.....	1-6
Table 2-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data.....	2-21
Table 2-2 – Pequannock Service Area Frequency Distribution Analysis	2-22
Table 2-3 – Summary of Statistical Parameters for Wanaque Lead Sampling Data.....	2-24
Table 2-4 – Wanaque Service Area Frequency Distribution Analysis.....	2-24
Table 3-1 – Key Water Quality Parameters for Corrosion Control Evaluation.....	3-3
Table 3-2 – Calculated CSMR Values from Available Chloride and Sulfate Data.....	3-11
Table 4-1 – Water Quality Analysis at Sequential Sampling Sites.....	4-4
Table 4-2 – Site A – South Ward Lead Results	4-5
Table 4-3 – Site B – North Ward Lead Results	4-7
Table 5-1 – General Characterization of Solid Phases in Pipe Deposits	5-4
Table 5-2 – Summary of Scale Composition Elemental Analysis Results.....	5-5
Table 5-3 – Comparison of Lead Sequential Sampling Data and EPA Scale Analysis Results	5-8
Table 7-1 – Model Input of Seasonal Water Quality Parameters.....	7-5
Table 7-2 – Model Input of Seasonal Chemical Addition Parameters.....	7-5
Table 7-3 – Theoretical Lead [Pb(II)] Solubility by Season (with Sodium Hypochlorite).....	7-6
Table 7-4 – Estimated Theoretical Lime Dose to Maintain Desired pH for Orthophosphate.....	7-9
Table 8-1 – Initial Tank Sizing for Orthophosphate Feed System.....	8-4
Table 8-2 – Summary of CCT Recommendations for Pequannock	8-11

Appendices

Appendix A Pipe Scale Analyses

This page intentionally left blank.

Section 1

Executive Summary

The City of Newark (Newark) exceeded the Lead and Copper Rule (LCR) Action Level for lead in the two sampling rounds in 2017 (January 2017 to June 2017 and July 2017 to December 2017) and in the first half of 2018 (January 2018 to June 2018). The Action Level for lead is 15.0 micrograms per liter ($\mu\text{g/L}$). The 90th percentile concentrations during these periods were as follows:

- January to June 2017 – 27.0 $\mu\text{g/L}$
- July to December 2017 – 26.7 $\mu\text{g/L}$
- January to June 2018 – 17.8 $\mu\text{g/L}$

Lead concentrations during these monitoring periods were higher in the Pequannock-supplied portions of the distribution system. The recent lead exceedances were the first in nearly 20 years of consistent compliance. The City first implemented sodium silicate for corrosion control treatment (CCT) in 1997; however, these recent lead exceedances indicate that the CCT at the Pequannock WTP is not currently optimized. Newark initiated a study in January 2018 to determine the causes of the recent exceedances.

This report addresses an assessment of the optimization of CCT for Newark's water supply. In January 2018, CDM Smith Inc. (CDM Smith), on behalf of Newark, commenced a corrosion control evaluation including the following studies:

- Statistical analyses and frequency distribution of lead data to understand the changing lead concentrations over time, and comparing the Pequannock and Wanaque systems
- Study of historic water quality trends impacting corrosion control
- Lead sequential sampling at selected residences in the system
- Pipe scale composition analyses performed by the United States Environmental Protection Agency (EPA)
- Lead solubility modeling

This report includes the results of these evaluations, which provide an understanding of the variability in water quality that occurred throughout recent history and the associated impacts on lead corrosion within Newark's system.

Historical Lead Concentrations

Figure ES-1 shows the frequency distribution of the historical LCR compliance sampling results on the Pequannock-supplied portion of the distribution system between 1992 and 2018. As can

be seen from **Figure ES-1**, lead results have increased significantly in the last three rounds, in some cases exceeding the original 1992 values prior to when CCT was implemented in 1997.

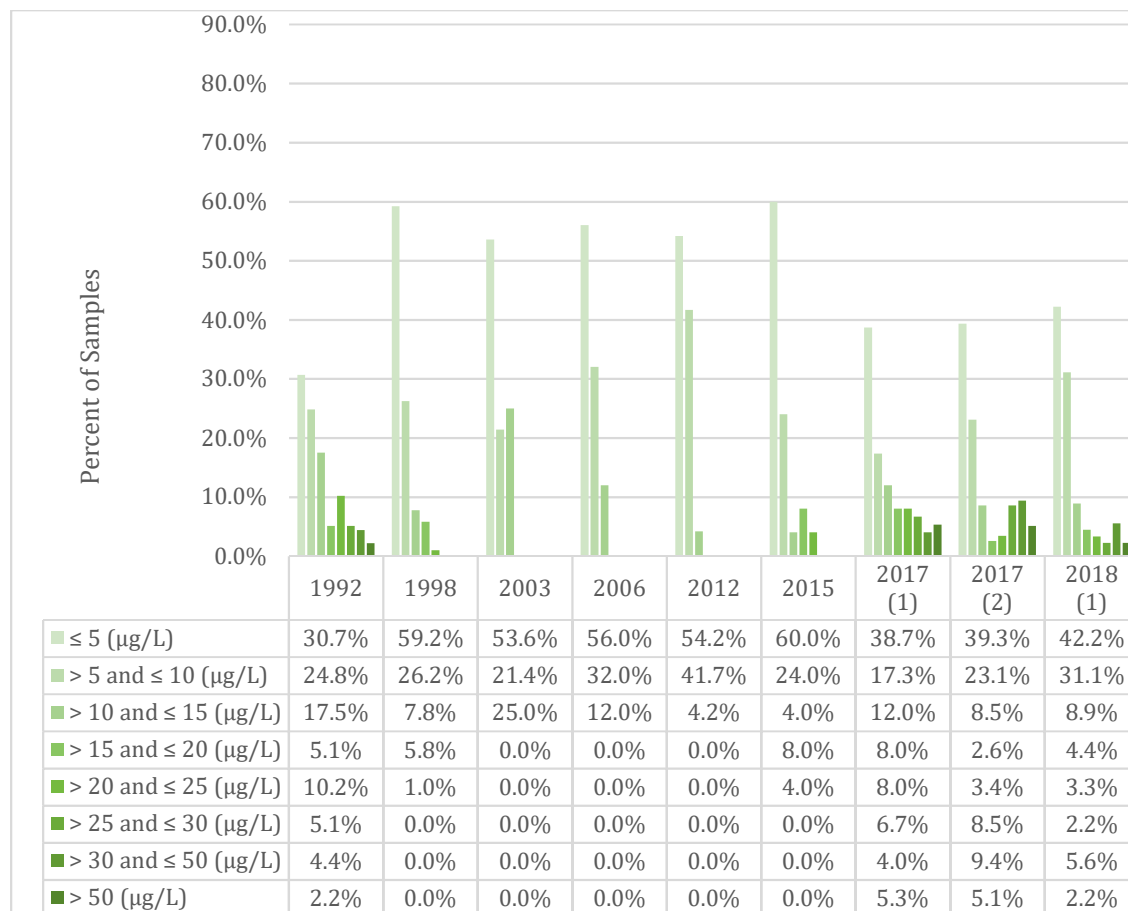


Figure ES-1 – Pequannock Service Area – Lead Sampling Data Percentage Frequency Distribution

Table ES-1 provides a summary of some statistical parameters based on the lead sampling compliance data in **Figure ES-1**.

Table ES-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data

Parameter	1992	1998	2003	2006	2012	2015	2017 (1)	2017(2)	2018 (1)
50th Percentile (µg/L)	8.5	4.0	4.8	4.1	5.0	0.0	7.4	7.8	6.4
75th Percentile (µg/L)	16.3	7.4	10.0	7.4	7.3	8.0	17.8	21.2	10.5
90th Percentile (µg/L)	26.8	12.3	12.2	9.5	9.7	15.8	29.8	36.0	22.9
Number of Samples (n)	137	103	28	25	24	25	75	117	90
Number of Samples >15 µg/L (n)	37	7	0	0	0	3	24	34	16
Percent > 15 & ≤ 25 µg/L	15.3%	6.8%	0.0%	0.0%	0.0%	12.0%	16.0%	6.0%	7.8%
Maximum (µg/L)	60.4	23.0	14.2	11.5	14.0	25.0	137.0	77.7	58.9

Scale Analysis

In February and March 2018, Newark took the initiative to send sections of three lead service pipes to the EPA Advanced Materials and Solids Analysis Research Core in Cincinnati, OH for characterization of the pipe scales. With the limited literature available and collective industry experience on sodium silicate, Newark understood the criticality of analyzing the pipe scales to gather more data specific to their system. Two of the pipes were excavated from the North Ward and one was excavated from the South Ward. After performing sequential sampling at Site A and Site B, sections of those lead service lines were also sent to the EPA Advanced Materials and Solids Analysis Research Core in October 2018 to compare the sample results with the scale analysis.

Analysis of pipe scales that reflect actual distribution system conditions provides a direct indication of the effectiveness of a current treatment protocol. Knowledge of the characteristics and behavior of the lead scales that have been formed in the service lines can be integrated with water quality, lead testing results and operational information to understand mechanisms of corrosion inhibition, speciation of metals and predictions of mobility/stability and can assist in implementation of corrective treatment changes. Knowing the chemical composition of a contaminant in distribution system scale materials can help with estimating the probability of unintended adverse consequences due to treatment or water quality changes.

Based on the testing performed by the EPA, the scales found on the outermost layers of the pipe walls were primarily hydrocerussite ($\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$), with cerussite (PbCO_3) and plattnerite (PbO_2) present as well. Hydrocerussite and cerussite are Pb(II) compounds that are carbonate-based scales. In carbonate-based scales, the hydroxide (OH^-), carbonate (CO_3^{2-}), or bicarbonate (HCO_3^-) ions bind with the metal (i.e., lead) to form metal/hydroxide/carbonate compounds of varying degrees of solubility on the interior wall of water pipes. Cerussite is the stable Pb(II) phase at pH 8–8.5. Cerussite is much more soluble than hydrocerussite, which is the stable Pb(II) phase at higher pH (≥ 9.0). It is unusual to find hydrocerussite as the dominant scale at Newark's current operating pH of around 7.4.

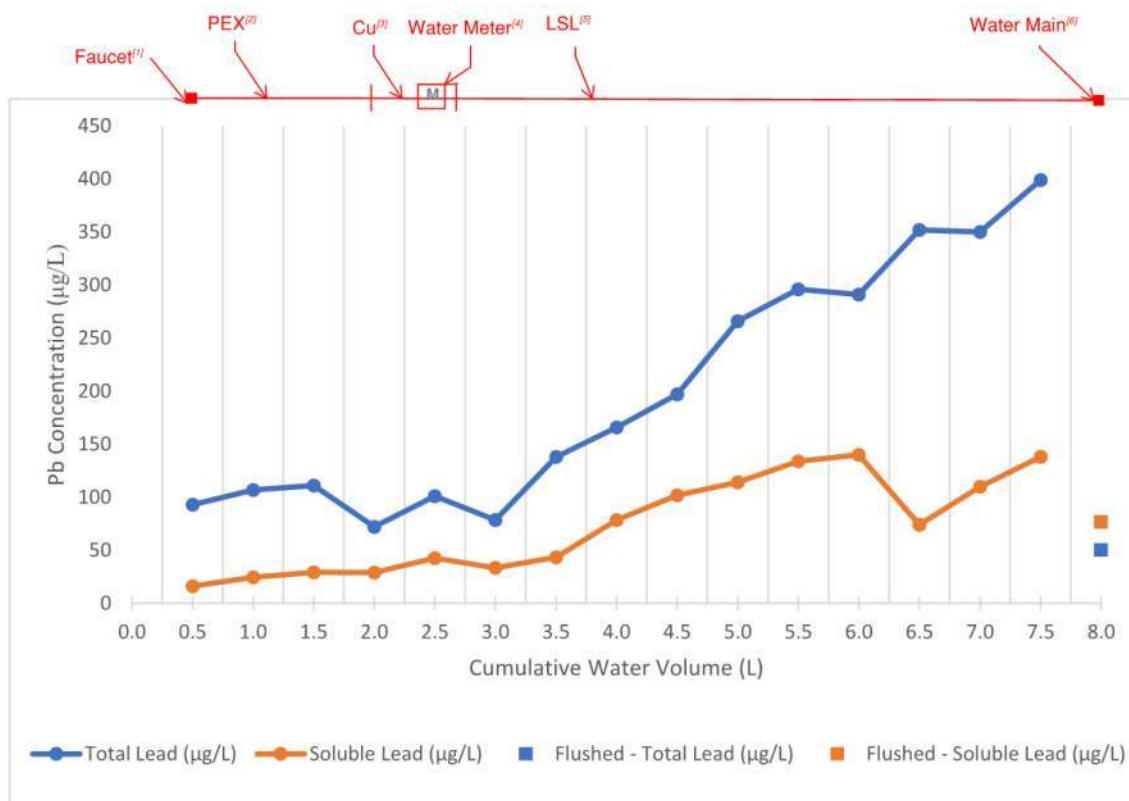
Plattnerite (PbO_2) is a Pb(IV) compound that is formed in waters with high redox potential (ORP). It is reported in the literature that a high ORP can be maintained when free chlorine is used (at levels typically over 1.5 mg/L), and that the rate of formation of PbO_2 appears to increase with increasing pH (Boyd, et al., 2008). Pb(IV) has also been observed in systems with free chlorine residuals less than 1.5 mg/L, including in Newark. Under these conditions, PbO_2 typically dominates or coexists with Pb(II) mineral forms, including hydrocerussite and cerussite. Plattnerite is appreciably less soluble than hydrocerussite and cerussite, making plattnerite more effective at maintaining low lead levels when the proper (high ORP) water chemistry is maintained.

The pipe scales did not contain any crystalline Si-Pb compounds, indicating that silicate complexation is not taking place and is not controlling soluble lead. However, a silica crust (SiO_2) was found on all three pipes. The silica crust was found to be porous and therefore was not acting as a barrier to the outward flux of lead from the pipe as the passivating layers (i.e. mainly plattnerite and hydrocerussite) were found forming behind, or closer to the pipe wall, than the silica crust.

The pH within the distribution system has a major impact on scale formation. In systems without orthophosphate, lead control relies on the formation of divalent lead carbonate scales or tetravalent lead (Pb(IV)) scales. For carbonate scales, such as cerussite and hydrocerussite, pH and alkalinity are critical parameters in their formation. For tetravalent lead, scale formation is dependent on pH, ORP and the presence of natural organic matter (NOM). Both types of scales were found in Newark's distribution system based on the scale analyses performed by the EPA.

Sequential Sampling

In September 2018, the City of Newark conducted sequential sampling at two locations with lead service lines (LSLs) and copper interior piping with lead solder. The purpose of this effort was to pinpoint potential sources of lead that exist within the service line and premise plumbing from the service connection in the street to the drinking water tap in the house. Sequential sampling is a tool to assist in developing an understanding of the system as part of the CCT optimization. The sources of lead at the tap measured in sequential samples can include LSLs, lead-based materials contained in the premise piping (e.g., leaded solder, brass/bronze fittings, galvanized piping), faucets, and water meters. The results are presented in Section 4 which indicate high lead levels of both soluble and insoluble forms in both the North and South Ward sampling locations. In comparison, higher lead levels were found in the South Ward location. **Figure ES-2** shows the sample results in a lead profile for the home tested in the South Ward compared with the associated plumbing component associated with that sample volume.



^[1] Kitchen Faucet Location, ^[2] Cross-Linked Polyethylene Pipe Segment, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Figure ES-2 – Site A – South Ward Lead Profile – September 10, 2018

In conclusion, the sequential sampling performed at opposite ends of Newark's distribution system show that the current corrosion practice is not optimized at controlling soluble lead release into the drinking water. Despite the silica concentrations in the water of approximately 8 mg/L as SiO₂ and the presence of a silica crust found in the EPA scale analysis (presented in Section 5), soluble lead was well above the EPA's lead Action Level. In addition, if a passivating scale was intact and functioning as a protective scale, lead levels would be expected to be much lower (Boyd, et al., 2008) than what was found.

The results confirm that the scales found on the pipes from the EPA scale analyses are not functioning as protective corrosion control scales under the current water quality conditions. Regarding particulate lead, both locations have appreciable particulate lead in the samples. This could be a result of sediment in the service line, particulates that collected in the aerator during the flushing prior to the stagnation period, active breakdown of the lead scale, some recent plumbing work performed by the homeowner, or most likely a combination of these factors.

Potential Causes of Recent Lead Exceedances

Based on the analyses performed over the course of this study, the following factors are most likely to have influenced the 2017-2018 elevated lead levels in Newark's distribution system. These are described in more detail in Section 6 as well as other possible contributing factors.

- Decrease in pH in the distribution system
- LCR compliance sampling

pH has fluctuated substantially for the delivered water, or distribution system point-of-entry (POE) measured at the "Test House", from the Pequannock WTP between 1992 and 2018 as shown in **Figure ES-3**. pH was maintained above 8.0 for several years. Starting in 2016, however, the pH declined to the current average of approximately 7.1.

Because both Pb(II) scales and Pb(IV) scales were found on Newark's LSLs and reducing pH negatively affects the formation of insoluble scales for both forms of lead, the reduction in pH in the Newark distribution system is likely the main cause for the 2017 and 2018 elevated lead levels. Raising pH to levels that will provide the desirable water chemistry for these scales to re-stabilize will risk Newark's ability to simultaneously comply with primary disinfection (CT) and disinfection byproduct regulations. Hence, returning to the corrosion control strategy Newark employed in the 1990s and early 2000s to comply with the LCR is no longer considered a viable option without other system upgrades to meet all regulations simultaneously.

It is not possible to confirm the exact duration of the elevated lead levels in Newark's distribution system. An underlying issue may have been developing that may not have been captured or discoverable in compliance sampling since testing was limited to first draw samples, as required by the regulations. This is discussed further in Section 6.

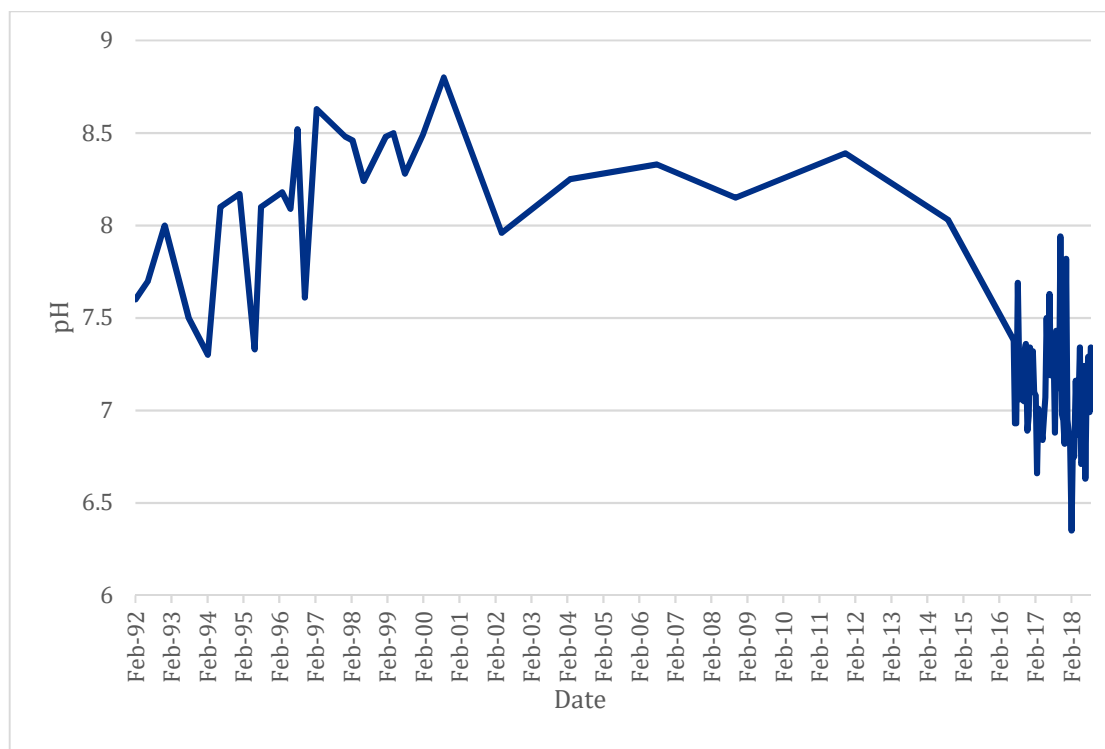


Figure ES-3 – Historic Pequannock WTP Delivered Water pH

Recommendations

With the results of the analyses performed in this study, several alternatives are recommended to reduce lead levels in the distribution system. The addition of orthophosphate is recommended to significantly reduce lead solubility without any adverse impacts on other water quality goals, e.g., without impacting simultaneous compliance with primary disinfection and disinfection byproduct regulations. The recommendations are summarized in **Table ES-2** and described in more detail in Section 8. The recommendations address both short-term implementation as well as long-term, sustained compliance with the LCR.

Table ES-2 – Summary of CCT Recommendations

Factor	Immediate CCT Recommendation	Longer Term CCT Recommendation	Additional Notes
Chemical	Zinc Orthophosphate	Zinc Orthophosphate	
Dosage	0.5 mg/L as PO ₄ increasing to passivation dose of 3.0 mg/L as PO ₄	Minimum 1.0 mg/L as PO ₄ (or as determined by pipe loop study)	Evaluate dosage in pipe loop study
Feed Location	Valley Road Rechlorination Station	Valley Road Rechlorination Station	
System pH	Stabilize pH to 7.3 to 7.4	Stabilize pH to optimal pH from pipe loop study	Evaluate optimal pH in pipe loop study
Sodium Silicate	Maintain current dose	Replace with a more cost-effective pH adjustment chemical	Evaluate any negative impacts from eliminating sodium silicate addition in pipe loop study

Factor	Immediate CCT Recommendation	Longer Term CCT Recommendation	Additional Notes
Demonstration Study	Conduct pipe loop study in parallel with implementation of immediate addition of zinc orthophosphate	Apply results of pipe loop study to long-term CCT plan	
Monitoring	Implement representative monitoring program, including sequential sampling	Continue monitoring program and sequential sampling until conditions are stabilized	
Public Health	Point-of-use filters and conduct public education program	CCT optimization and LSL Replacement Program	

Section 2

Background

The City of Newark (Newark) supplies approximately 80 million gallons per day (mgd) of potable water to a population of over 300,000 customers located in Newark, NJ and its surrounding communities. Newark's population of approximately 280,000 is supplied potable water through a large, complex system that is managed by the City of Newark's Department of Water and Sewer Utilities (Department).

Redacted for Privilege

During the January to June 2017 Lead and Copper Rule (LCR) sampling round, Newark exceeded the Action Level (AL) for lead at the 90th percentile, based on a total number of samples of 233 customers. On July 11, 2017, the New Jersey Department of Environmental Protection (NJDEP) sent a letter to Newark that outlined a series of required actions in response to the Lead Action Level exceedance. Of the requirements, NJDEP required Newark to submit an Optimal Corrosion Control Treatment (OCCT) recommendation in accordance with 40 CFR 141.82(a) no later than six (6) months after the monitoring period when the action level was exceeded, or by December 31, 2017.

In response to NJDEP, Newark submitted an OCCT Memorandum on December 27, 2017. The 2017 OCCT Memorandum outlined the following recommended actions:

- Continuing to collect the Water Quality Parameter data “to ensure proper corrosion control treatment”
- Completion of a corrosion control optimization desktop study
- A coupon study at several locations in the distribution system
- Pipe loop testing

The 2017 OCCT Memorandum set the following as target Water Quality Parameters (WQPs) to be maintained for the Pequannock system:

- pH over 7.2
- Alkalinity over 30 mg/L
- Silica over 6.0 mg/L as SiO₂

Newark also stated they would increase the sodium silicate dose to 12-15 mg/L from 8-12 mg/L, effective July 24, 2017.

Since the 2017 OCCT Memorandum was issued, Newark has exceeded the Lead Action Level in the second half of 2017 and the first half of 2018. Newark is currently evaluating both immediate and long-term measures to minimize lead levels throughout the system. Specifically, Newark is looking to: a) implement a program to replace all lead service lines in Newark; and b) optimize corrosion control treatment. Newark’s initiative to replace all lead service lines in the City is being performed under a separate project and is not discussed in this report.

This report addresses the optimization of corrosion control treatment for Newark’s water supply. Provided herein are the results of CDM Smith’s evaluations of historic and current water quality in the source water and distribution system. These evaluations provide an understanding of the variations in water quality that occurred throughout recent history and the associated impacts on lead corrosion within Newark’s system. With this understanding, several alternatives were considered to reduce lead solubility in the distribution system. Recommendations are provided for short-term implementation as well as long-term, sustained compliance with the LCR.

2.1 Current Corrosion Control Treatment (CCT)

The Pequannock WTP has dosed sodium silicate at the plant since 1997, based largely on the Corrosion Optimization Study prepared by the City of Newark in June 1994. The Wanaque WTP has dosed zinc orthophosphate upstream of their Belleville Reservoir Complex since the mid-1990s. Details on the current CCT implemented in both water supplies are discussed in this section of the report.

2.1.1 1994 Corrosion Optimization Study

When the LCR was established in 1991, both the Pequannock and Wanaque systems experienced high lead levels when performing the initial requisite monitoring programs in 1992 and 1993. At that time, both systems commenced corrosion control studies and implemented corrosion control treatment (CCT) in the mid- to late-1990s.

The Pequannock WTP implemented CCT based on a study performed by the Division of Water/Sewer Utility and summarized in a report, “City of Newark Report on Corrosion Optimization Study,” dated June 1994. The study included bench-scale testing and a pipe loop study evaluating the effectiveness of the following corrosion inhibitors:

- Increased lime (to increase pH)
- Orthophosphate
- Ortho-poly blended phosphate
- Sodium silicate

The bench-scale testing involved a two-cell corrosion test device where raw water was fed into the first cell and mild steel metal coupons were suspended in both cells. A corrosion inhibitor was applied to the water before it entered the second cell (Newark, 1994). The anticipated percent reduction of lead leaching for each of the inhibitors was estimated based on a function of weight loss by the mild steel coupons which were used as a surrogate for lead. The estimated reductions were as follows:

- 15% reduction for lime, pH 8.5 to 9.0 maintained
- 50% reduction for zinc orthophosphate based on a dose of 1 mg/L as PO_4 (pH not specified)
- 40% reduction for ortho-polyphosphate blend (dose and pH not specified)
- 45% reduction for silicate based on a dose of 20 mg/L as SiO_2 for 1 month and a dose of 9 mg/L as SiO_2 (pH not specified)

The bench-scale tests were followed by pipe loop experiments. The pipe loops had new ½-inch lead and copper piping and flow was maintained at 1 gallon per minute (gpm) to simulate typical flow in a home. The loops were run without any addition of a corrosion inhibitor for the first 6 weeks at a pH of approximately 7.3. By the end of the 6 weeks, the pipe loops were considered “stabilized” and results were showing consistent water quality characteristics across all six (6) pipe loops, including lead concentrations (Newark, 1994). Subsequent testing was performed with orthophosphate and an ortho-polyphosphate blend for 26 weeks and with silicate for 40 weeks. Sodium silicate was tested at dosages ranging from 8 mg/L to 24 mg/L, which raised the pH of the water to between 8.4 and 9.0 (Thompson, 1997). Although not specifically stated in the study, it is assumed that the dosages are presented in units “as silica (SiO_2)”. If the dosages were “as silica,” then the “as sodium silicate product” dose would be approximately three (3) times these values, or 24 mg/L and 72 mg/L, respectively. The silicate treatment proved to be effective

under these conditions, reducing lead release from lead pipe by 65% and from lead-soldered copper pipe by 60% over the control.

Orthophosphate also proved to be effective at a pH of 7.4 to a similar degree as the silicate, but was eliminated since it could not be dosed at the plant upstream of the Cedar Grove Reservoir without risking algae growth in the open reservoir. At the time, the author of the study stated that the City would have to construct “a number of satellite feeding stations which may involve substantial capital improvements and, hence, create a liability to the City’s financial implication.” (Newark, 1994). At the time, the City was providing treated water to other municipalities upstream of the Cedar Grove Reservoir. Currently, only the Township of Pequannock is fed upstream of the Cedar Grove Reservoir, other than emergency interconnections.

The 1994 report noted that Newark also had concerns with phosphates due to a prior experience involving water complaints following the addition of a polyphosphate blend at the Pequannock WTP for 2 years in the mid-1980s. Newark stopped using the polyphosphate due to these complaints, as well as severe algae growth in the Cedar Grove Reservoir (Newark, 1994).

Newark ultimately recommended sodium silicate as the optimal corrosion control treatment, at a starting dose of 18-20 mg/L for an initial passivation period then decreasing to an 8 mg/L maintenance dose (Newark, 1994). It is believed that the recommended dose was provided “as silica (SiO₂)”. The raw water silica concentration was reported to be 4.0 mg/L (Newark, 1994); therefore, the residual silica concentration would be expected to be approximately 12 mg/L in the finished water. No final pH was recommended; however, the pipe loop testing was performed at a pH of 8.5 to 9.0, which was achieved through the addition of lime and silicate.

Research on sodium silicate was limited at the time of the 1994 report. Since that time, it is believed that silica does not complex with lead in a similar manner to orthophosphate which forms lead compounds with low solubility (Taylor, et al., 2008). Instead, silicate helps to raise the pH which promotes the formation of lead-carbonate scales at higher pH values. See Section 7 regarding sodium silicate research and available literature.

2.1.2 Treatment Modifications Impacting Corrosion Control Since 1994

In 2003-2004, the Pequannock WTP supply was reduced from approximately 50-60 mgd to 40-45 mgd in order to reduce loading rates on the filters to meet stricter regulations on turbidity and disinfection byproducts. The difference was made up by increasing the Wanaque supply at the Wayne Pump Station to its current 10 to 15 mgd, which is blended with the Pequannock water and distributed to customers in Newark’s high-pressure gradients. The Wanaque water does not have any corrosion inhibitor when it is blended with the Pequannock water at Wayne. This dilutes the sodium silicate concentration prior to distribution to customers downstream of the Cedar Grove Reservoir. Based on our review of operational records, it is unclear if the sodium silicate dose was increased to account for the additional flow from Wanaque or if the effective feed rate to the Pequannock WTP supply was reduced, subsequently reducing the dose in the blended water.

Other changes to treatment that have occurred at the Pequannock WTP since the original pipe loop testing include:

- Between 2015 and 2018, finished water pH was maintained at the Pequannock WTP at approximately 6.9 to 7.3. The finished water pH is currently maintained below 7.4 and is averaging below 7.0 in order to achieve primary disinfection (CT) and minimize formation of disinfection byproducts. In the late 1990s, pH was maintained around 8.5 based on the recommendations from the 1994 pipe loop study. See Section 3.3, Historic Water Quality Trends, for additional information on pH over time.
- The quicklime system was replaced with a hydrated lime system in April 2017. Although upgrades were subsequently made to the hydrated lime system to improve performance and output in September 2018, the primary driver for the lower pH is the need to meet primary disinfection requirements and not a result of equipment failures.
- The current sodium silicate system occasionally struggles to meet the desired dose of 12 to 15 mg/L as sodium silicate for corrosion control. On average, a dose of 7 mg/L is applied to keep pH at a lower value to meet disinfection requirements.

2.1.3 Current Corrosion Control Treatment

Pequannock Supply

As noted above, the water supply to Newark's higher-pressure gradients (above 200 feet) is a blend of treated water from the Pequannock WTP and Wanaque water that is fed at the Wayne Pump Station upstream of zinc orthophosphate addition to the Wanaque supply. The Pequannock pressure gradients include almost all homes located in the West and South Wards and a majority of homes located in the Newark's North and Central Wards. As a result of the recent lead exceedances in these areas, Newark increased the sodium silicate dose from 8-12 mg/L to 12-15 mg/L as sodium silicate, or as close as possible to this dose with the existing equipment, in July 2017. The target dosage was equivalent to approximately 3.5-4.4 mg/L as silica (SiO_2), approximately half of the recommended dose from Newark's 1994 study. If Newark was to double the sodium silicate dose, the pH would increase accordingly, potentially creating issues with Stage 2 Disinfection Byproduct Rule compliance and meeting primary disinfection requirements at the plant. The sodium silicate target dose can be difficult to maintain during the cold winter months while consistently also meeting disinfection requirements since sodium silicate raises pH.

In the 2017 OCCT Memorandum, Newark stated that their target is to maintain a residual silica concentration of 6 mg/L throughout the distribution system. The silica concentration is measured in the plant finished water (Test House) and in the distribution system on a bi-weekly basis. Since the raw water provides approximately 4.0 mg/L of naturally occurring silica (Newark, 1994), only an additional 2 mg/L of silica (or approximately 6.9 mg/L of sodium silicate) is required to be added to meet this target. When the silicate treatment was first initiated, it is assumed that the silica concentrations in the distribution system would likely have been closer to 12 mg/L (approximately 8 mg/L from the sodium silicate and approximately 4 mg/L from the raw water). If the report recommendations were followed, the initial silica residual would have been 28 mg/L (24 mg/L from the sodium silicate and approximately 4 mg/L from the raw water). No data is available to confirm the initial dose of silicate or the initial silica residuals in the distribution system when the corrosion control treatment was first implemented.

Wanaque Supply

Newark's 165-foot pressure gradient is primarily comprised of the East Ward and small sections within the North, Central and South Wards. The 165-foot pressure gradient is supplied by water treated at the Wanaque WTP. The Wanaque supply to this system has been adding zinc orthophosphate upstream of the Belleville Reservoir Complex, but downstream of the Wayne Pump Station, since the mid-1990s. The Wanaque system maintains a pH of approximately 7.6 and doses approximately 1.2 mg/L as orthophosphate. This area has experienced much lower lead concentrations since implementing CCT in the 1990s than the regions supplied by the Pequannock WTP. Therefore, this study focuses on the sections of the distribution system supplied by the Pequannock WTP, as shown in **Figure 2-1**.

Recent CCT Optimization Efforts

In February 2018, CDM Smith Inc. (CDM Smith), on behalf of Newark, commenced a corrosion control evaluation including the following studies:

- Statistical analyses and frequency distribution presentations to understand the changing lead concentrations over time, and comparing the Pequannock and Wanaque systems
- Study of historic water quality trends impacting corrosion control
- Lead sequential sampling at residences in areas of concern in Newark's distribution system
- Pipe-scale composition analysis performed by the United States Environmental Protection Agency (EPA) of pipes located in areas of concern in the system
- Lead solubility modeling

The results of these studies are provided in this report in Sections 2.3, 3, 4, 5 and 7.

2.2 Lead and Copper Rule Compliance Sampling Results

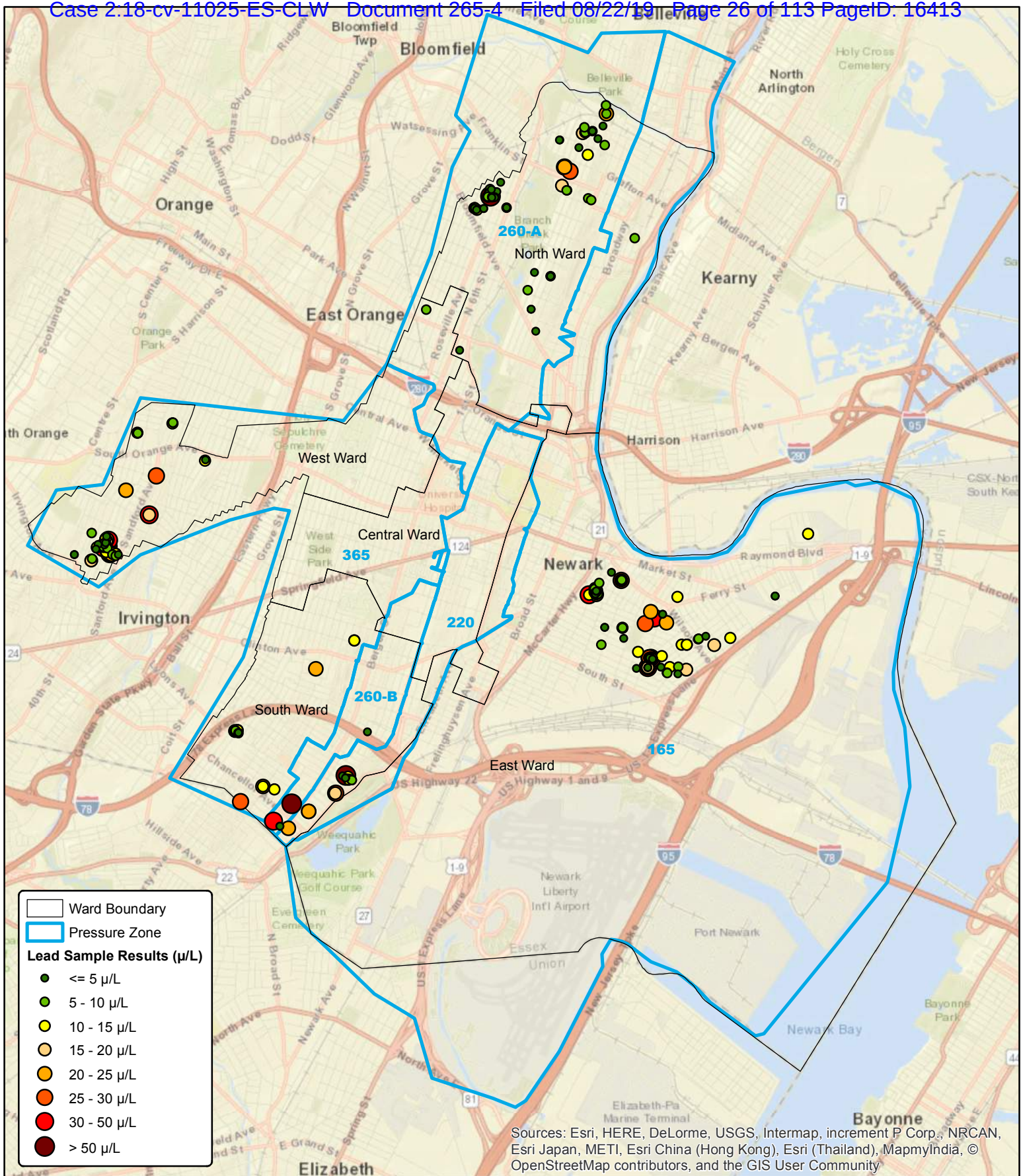
As discussed above, due to consecutive rounds of Lead Action Level exceedances in 1992 (90th percentile above the Action Level of 15 µg/L), both the Pequannock and Wanaque systems implemented CCT in the 1990s. After 1992, water quality data is available for the subsequent residential LCR compliance sampling performed in 1998, 2002, 2003, 2006, 2009, 2012, 2015, 2017, and the first half of 2018. The second round of sampling in 2018 (from July to December) is ongoing at the time of the preparation of this report. This analysis focuses on residential sampling. Additional sampling has been performed at schools with similar results.

Maps showing the locations and lead concentrations for all compliance sampling events, including the initial sampling in 1992 leading to implementation of CCT, are provided in **Figures 2-2 through 2-12**. As shown in the figures, Newark did experience a period with very low lead concentrations in their sampling pool between 1998 and 2012. During this period, the compliance sampling locations varied. For example, in 2002 and 2009, only homes receiving Wanaque water were sampled. In 1998 and 2006, only homes receiving Pequannock water were sampled. In 2015, slightly elevated lead concentrations were found, but they were still below the Action Level. During the subsequent sampling rounds, lead levels exceeded the Action Level during the first and second half of 2017, as well as the first half of 2018. The Action Level was also

exceeded in the last two sampling rounds by Newark's consecutive system, Bloomfield, which receives a large percentage of its supply from Newark's Pequannock WTP.

As corrosion control chemistry transitions are a slow process, it cannot be determined exactly when the lead levels started to increase. To monitor the transition of potential high lead levels, Newark has followed the acceptable practice of maintaining routine monitoring of the WQPs, as well as, continuing tap sampling under the LCR.

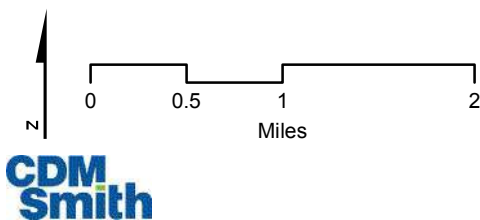
The LCR Action Level for copper is 1.3 mg/L at the 90th percentile value. Newark has not experienced high copper levels in their system based on the data analyzed. Optimization of treatment for copper, therefore, is not addressed in this report.

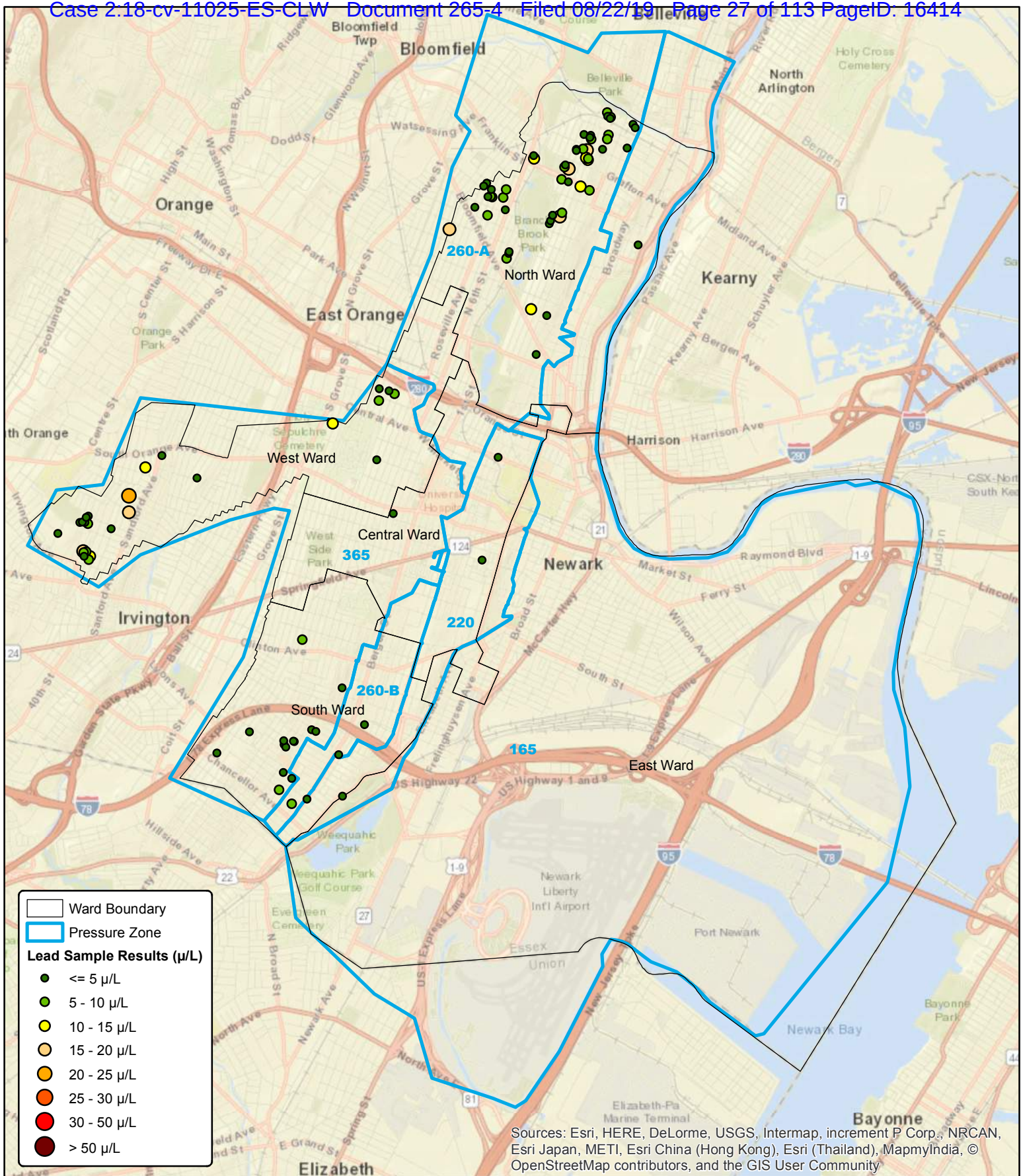


Lead Level in the City of Newark

Data Collected: 1992

Figure 2-2

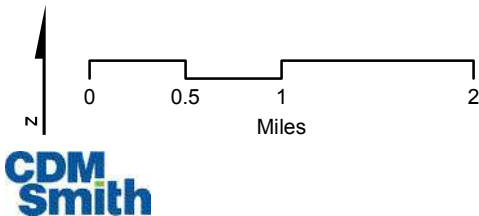


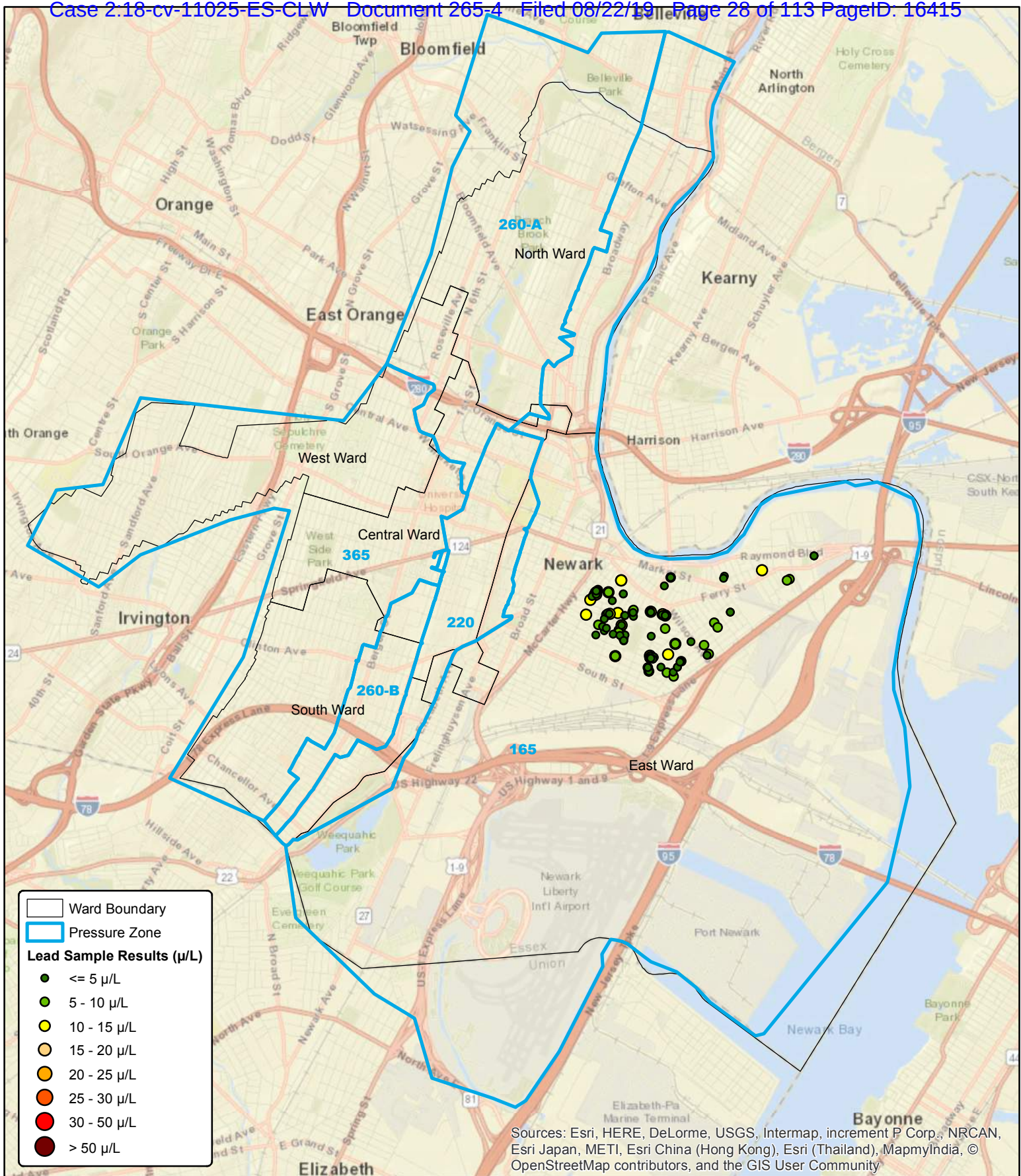


Lead Level in the City of Newark

Data Collected: 1998

Figure 2-3

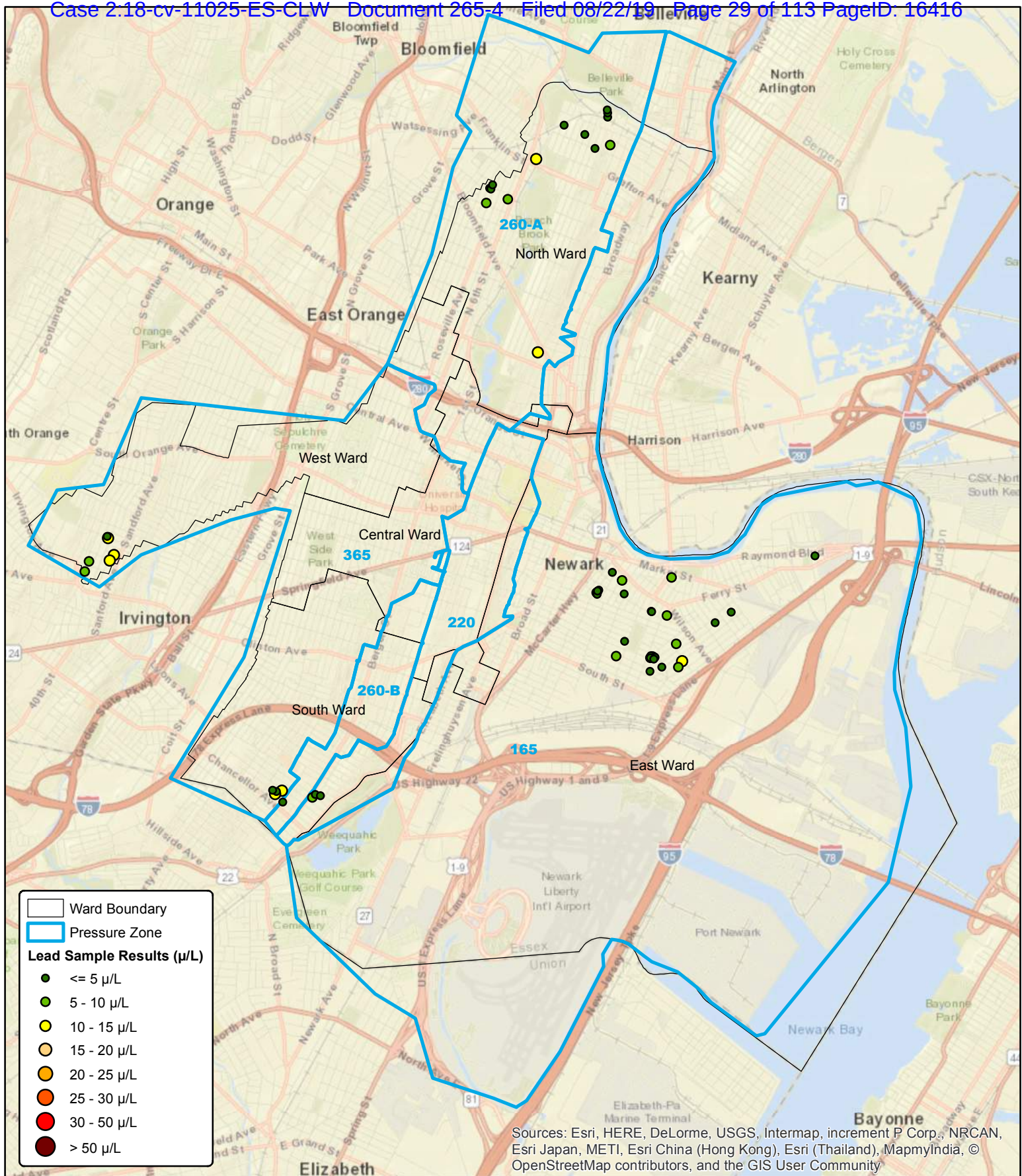




Lead Level in the City of Newark

Data Collected: 2002

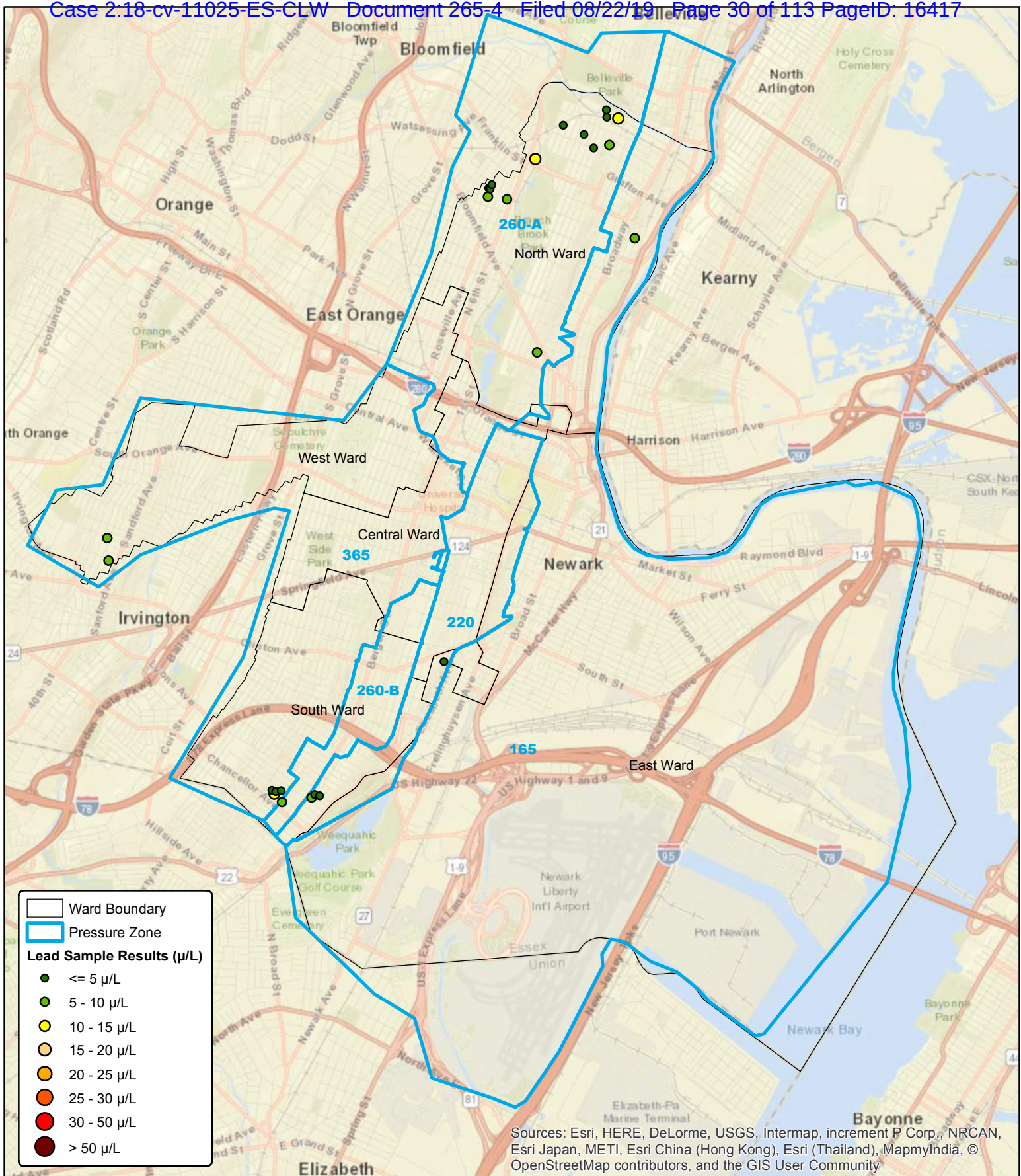
Figure 2-4



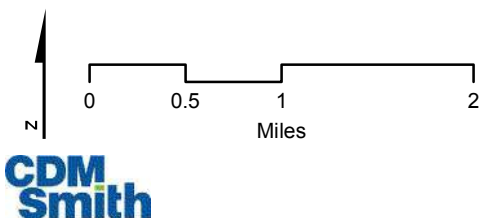
Lead Level in the City of Newark

Data Collected: 2003

Figure 2-5



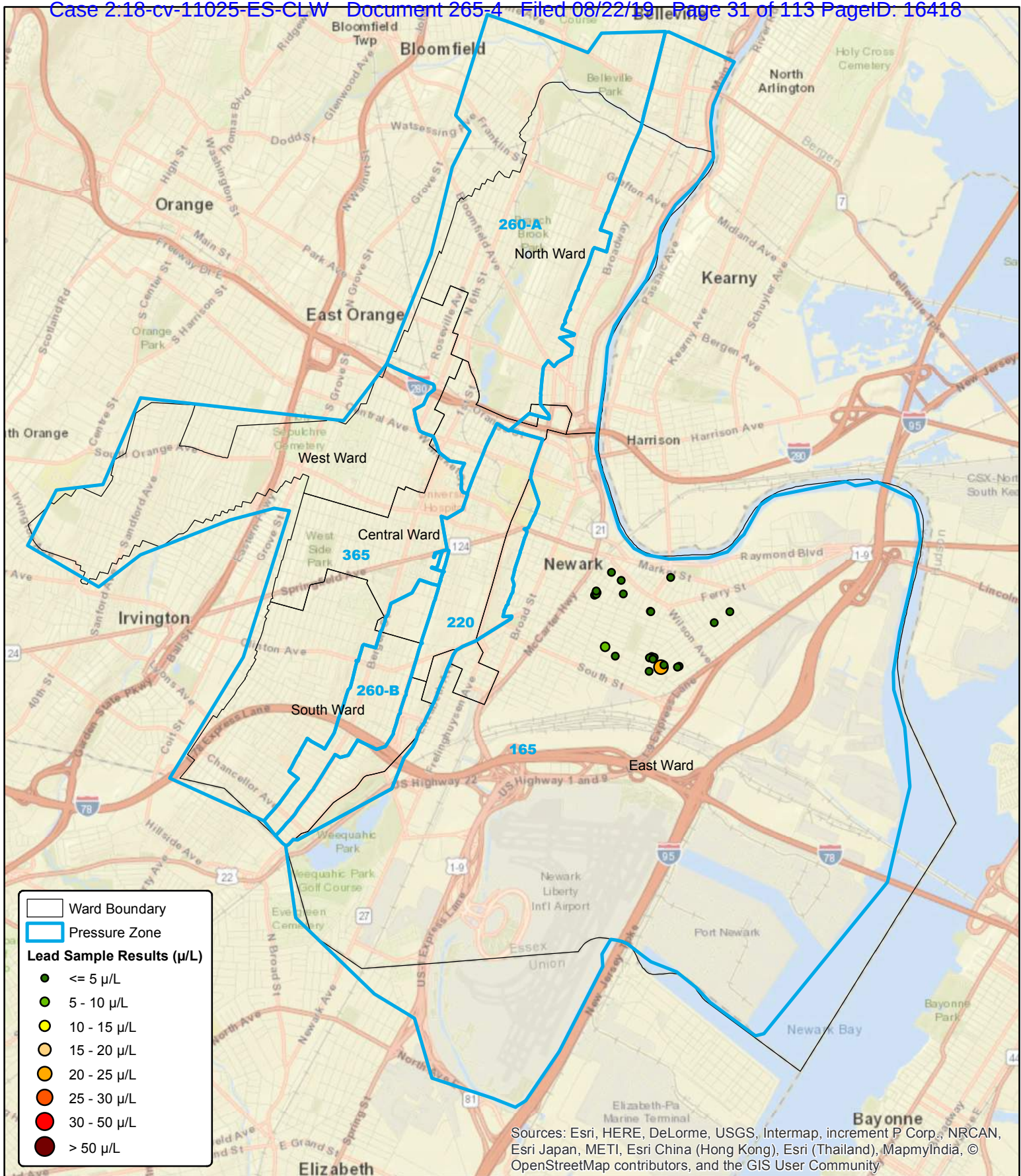
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Lead Level in the City of Newark

Data Collected: 2006

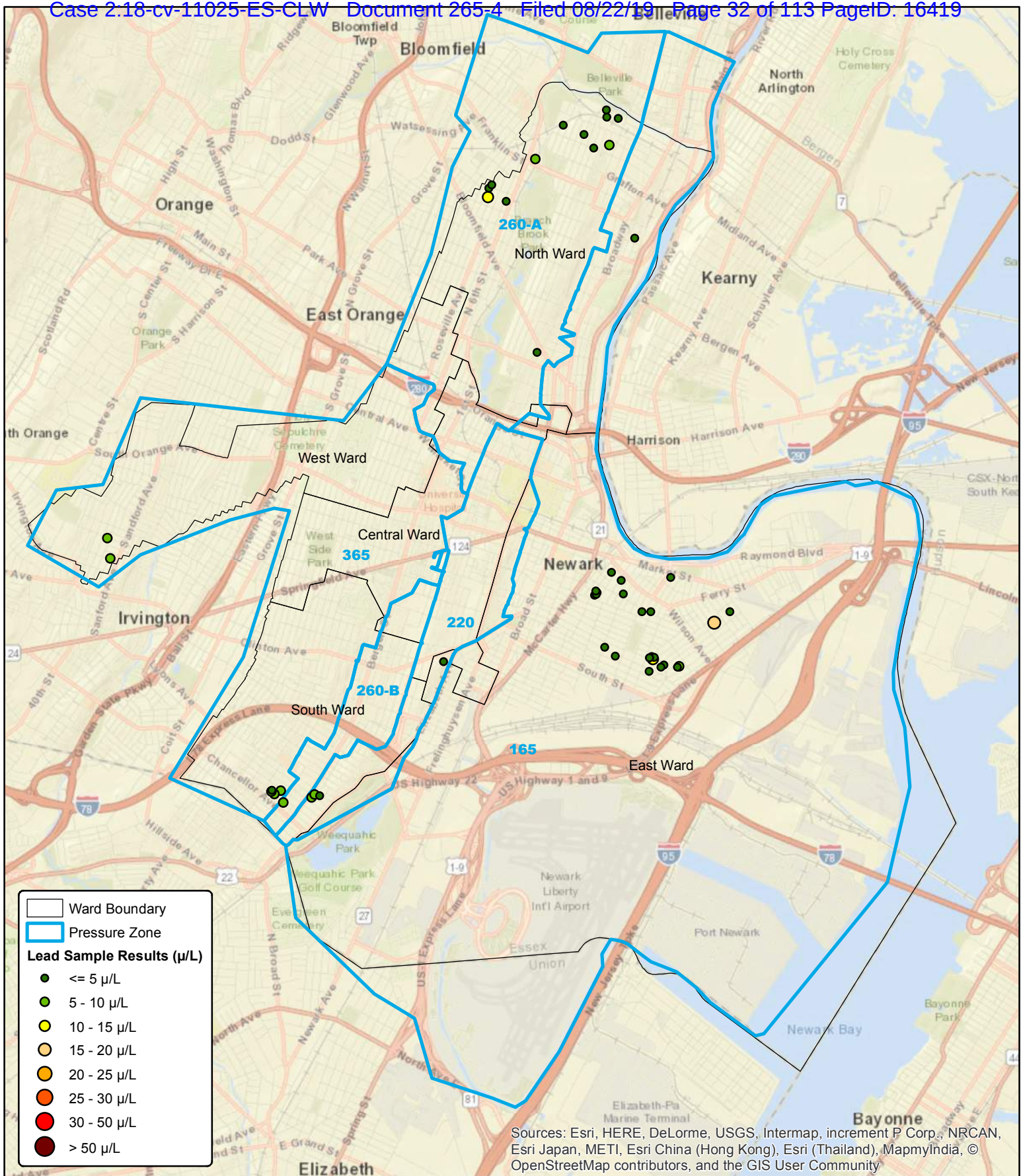
Figure 2-6



Lead Level in the City of Newark

Data Collected: 2009

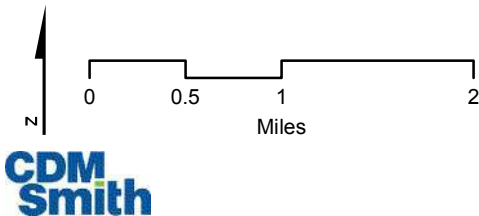
Figure 2-7

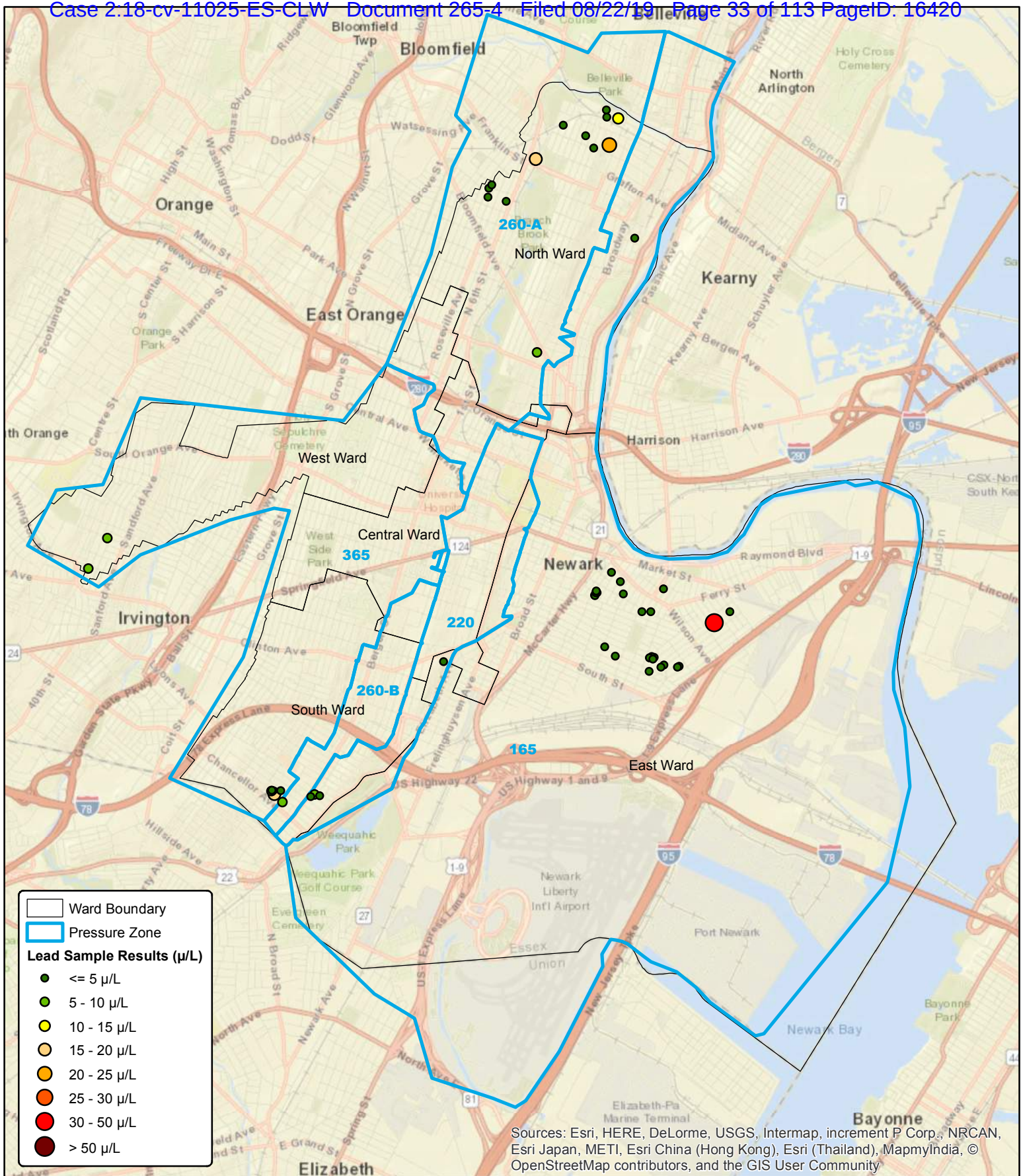


Lead Level in the City of Newark

Data Collected: 2012

Figure 2-8

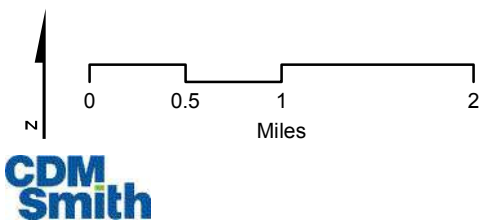


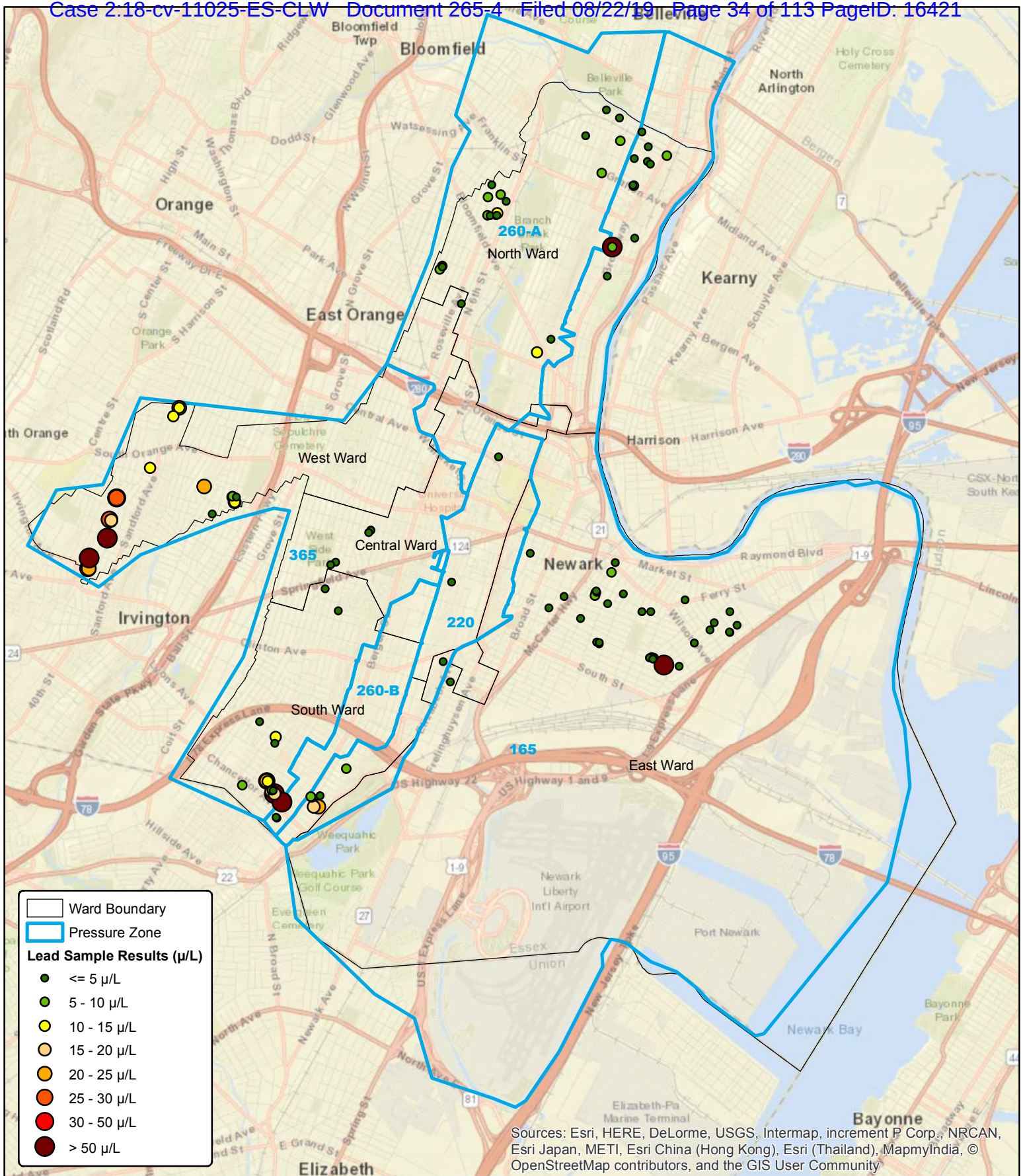


Lead Level in the City of Newark

Data Collected: 2015

Figure 2-9

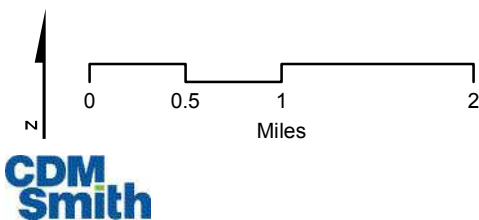


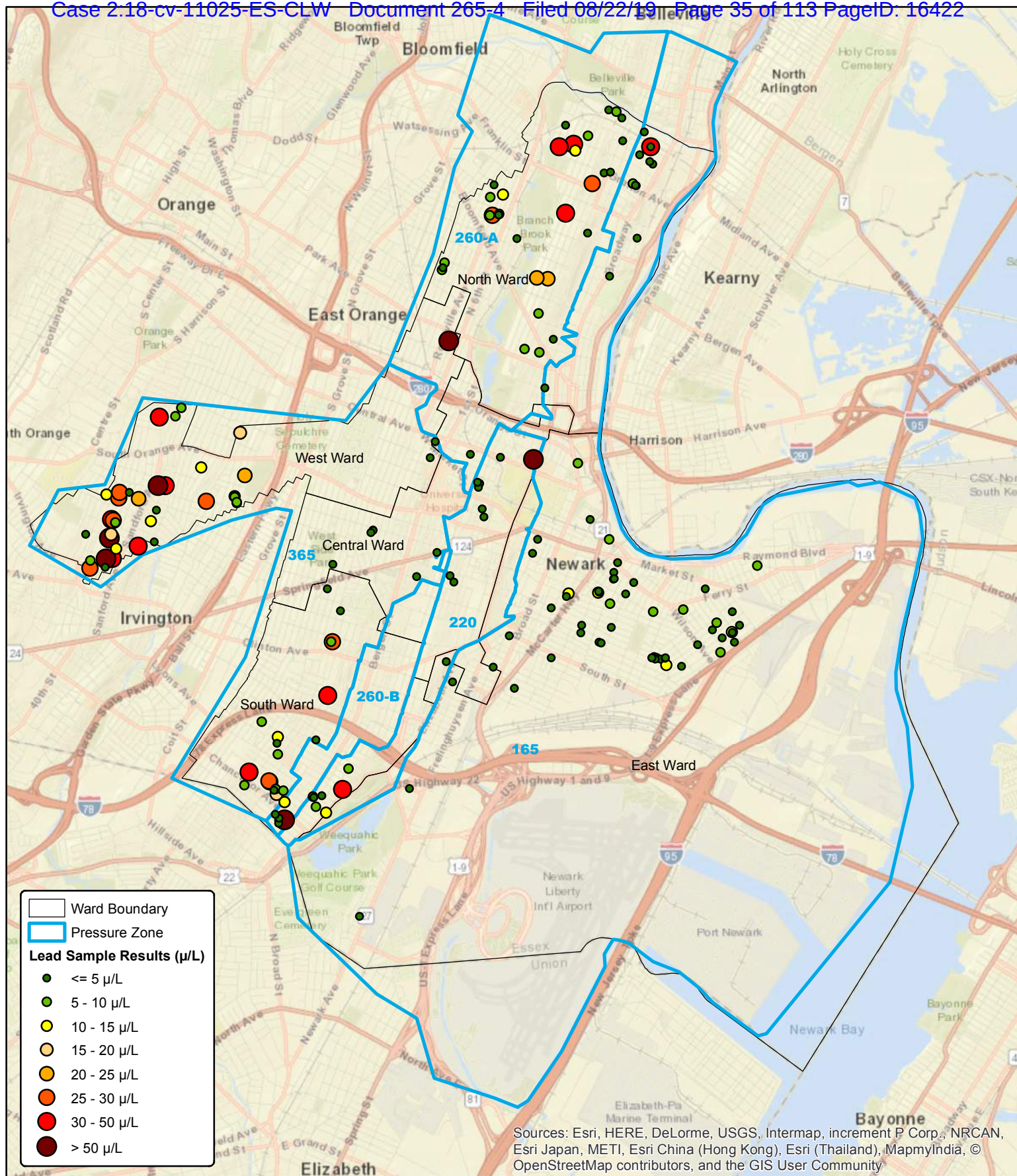


Lead Level in the City of Newark

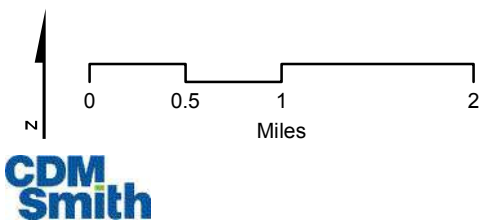
Data Collected: January - June 2017

Figure 2-10





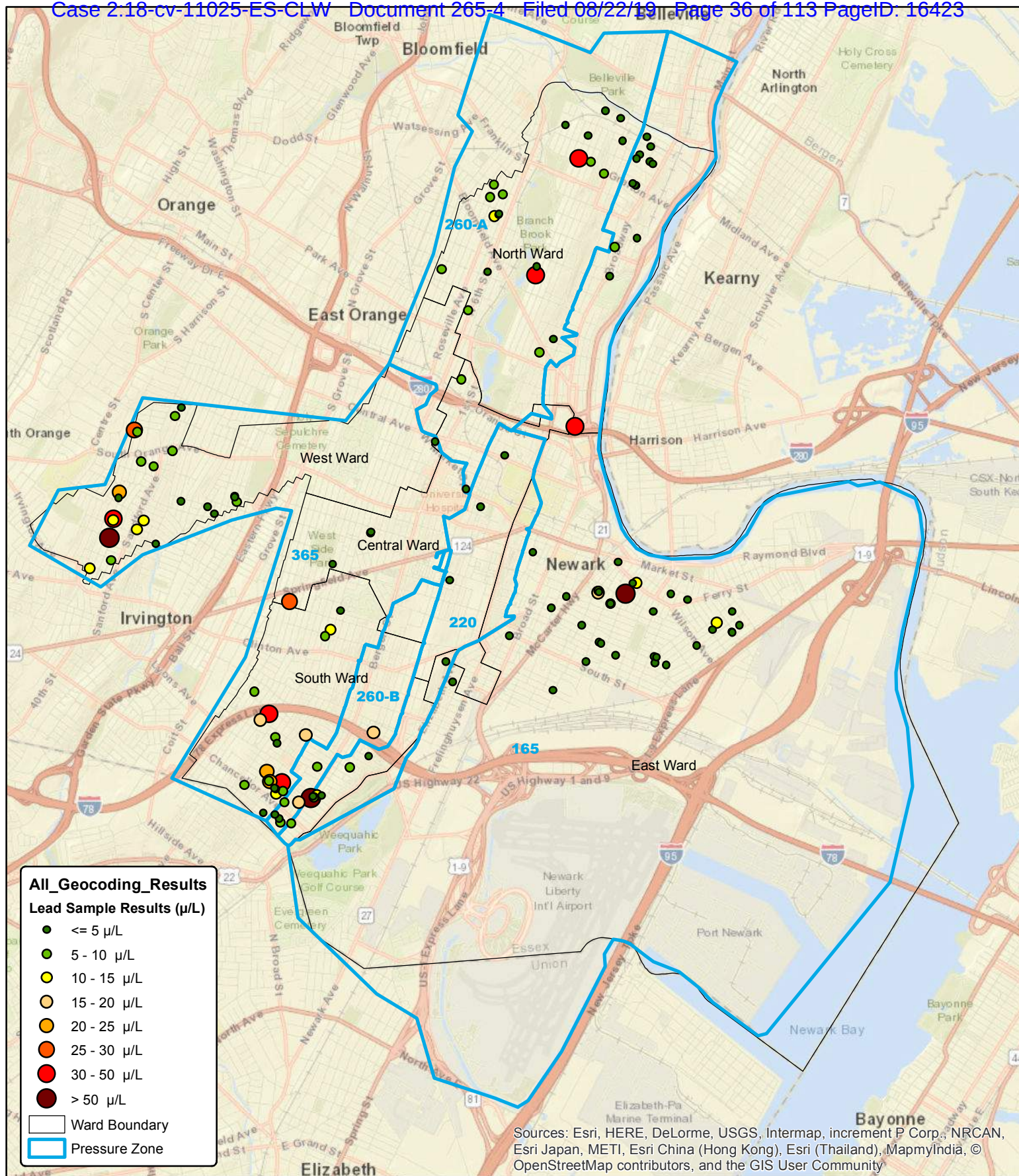
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Lead Level in the City of Newark

Data Collected: July - December 2017

Figure 2-11

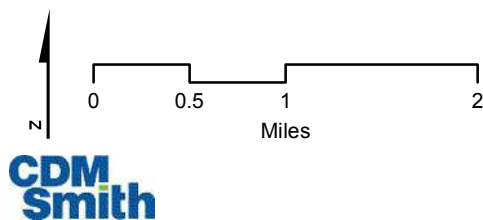


Lead Level in the City of Newark

Data Collected: January - June 2018

Figure 2-12

angellja G:\NewarkLeadServiceLine\02_MXD\Jan_June2018Results\LeadSamples2018.mxd 7/20/2018



2.3 Lead Frequency Distribution

A frequency distribution analysis was conducted using multiple rounds of compliance sampling data for both the Pequannock and Wanaque service areas. The analysis was conducted for each service area separately as the service areas receive different CCT as described in Section 2.1. Although regulatory compliance is based on the City of Newark as a whole, the corrosion control chemistry of the two service areas differ. Therefore, the systems were evaluated separately to understand the cause of the high lead levels.

Frequency distributions can provide insight as to whether changes in lead levels may be the result of CCT, sampling variability, or a combination of the two. (Burlingame, 2004) Frequency distributions can assist in establishing the cause of a change in the 90th percentile value and Action Level exceedance. The frequency distribution presented in this Section provides an analysis of the lead sampling results collected since 1992. The data were sorted into several “bins” and percentile categories by lead concentration. The three “bins” that provide the best indication of whether or not CCT has been optimized are: (1) percent less than or equal to 5 µg/L, (2) 50th (median) percentile (µg/L), and (3) percent greater than 15 µg/L and less than or equal to 25 µg/L. Overall trends are also revealed by the frequency distribution data.

2.3.1 Lead Frequency Distribution – Pequannock Service Area

For the Pequannock service area, the frequency distribution analysis was conducted for compliance sampling data collected in 1992, 1998, 2003, 2006, 2012, 2015, the two sampling periods in 2017, and the first period in 2018. Lead sampling rounds were also conducted by the City of Newark in 2002 and 2009; however, samples taken during these periods were concentrated in areas outside of the Pequannock service area.

Figure 2-13 provides an overview of the lead sampling compliance data from the nine (9) sampling events for the Pequannock service area for the different “bins” from less than 5 µg/L to greater than 50 µg/L. **Table 2-1** provides a summary of some statistical parameters based on the lead sampling compliance data, and **Table 2-2** provides an interpretation of the findings of the frequency distribution analyses for the Pequannock service area.

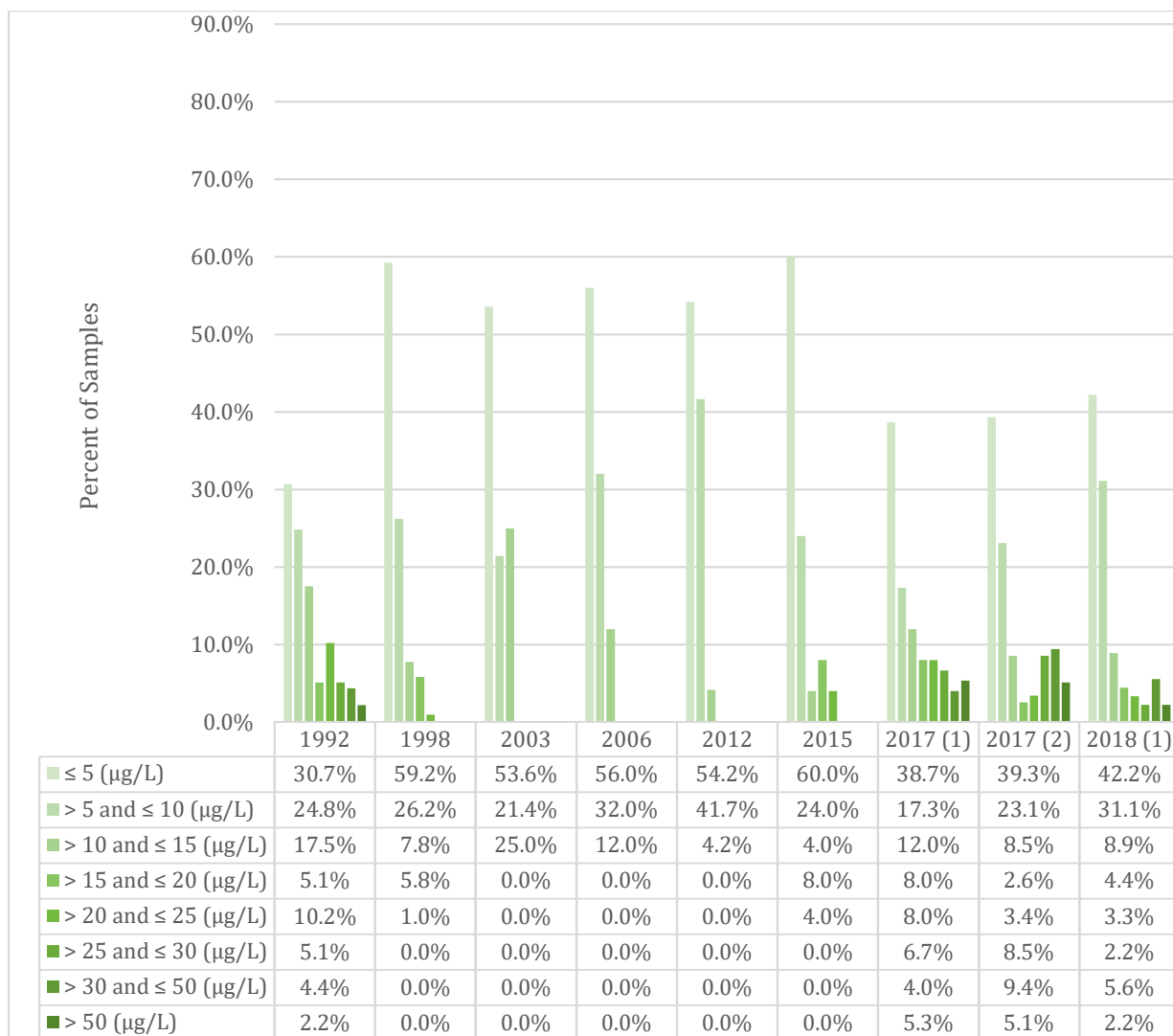


Figure 2-13 – Pequannock Service Area – Lead Sampling Data Percentage Frequency Distribution

Table 2-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data

Parameter	1992	1998	2003	2006	2012	2015	2017 (1)	2017(2)	2018 (1)
50th Percentile (µg/L)	8.5	4.0	4.8	4.1	5.0	0.0	7.4	7.8	6.4
75th Percentile (µg/L)	16.3	7.4	10.0	7.4	7.3	8.0	17.8	21.2	10.5
90th Percentile (µg/L)	26.8	12.3	12.2	9.5	9.7	15.8	29.8	36.0	22.9
Number of Samples (n)	137	103	28	25	24	25	75	117	90
Number of Samples >15 µg/L (n)	37	7	0	0	0	3	24	34	16
Percent > 15 & ≤ 25 µg/L	15.3%	6.8%	0.0%	0.0%	0.0%	12.0%	16.0%	6.0%	7.8%
Maximum (µg/L)	60.4	23.0	14.2	11.5	14.0	25.0	137.0	77.7	58.9

Table 2-2 – Pequannock Service Area Frequency Distribution Analysis

Data Category/Bin	What does it tell us?	Newark Pequannock Pb Results
Overall frequency distribution	Gives a comprehensive picture of sampling results and allows for comparisons over different periods of time.	The Pequannock WTP implemented sodium silicate chemical addition for CCT in 1997. The lead results from 1998 through 2012 reflect effective control of lead release. However, starting in 2015, lead levels returned to and, in some cases, exceeded 1992 levels. This points to a significant change in system behavior around 2015.
Less than or equal to 5 µg/L	Typically, optimization of a corrosion control treatment is signified by an increased percentage of values that are less than 5 µg/L. When water is treated to be less corrosive, or chemistry is modified to create a stable and insoluble lead compound, overall lead levels will decrease, thereby increasing the percentage of samples with the lowest lead concentrations.	The percentage of samples less than or equal to 5 µg/L increased after CCT was implemented (1997). However, this category only saw 60% of the samples at best, compared to optimized systems which typically see well above 80% of samples less than 5 µg/L. In 2017, the number of samples less than 5 µg/L decreased significantly from 50-60% to about 40%.
50th percentile (µg/L)	The nature of the 90th percentile Action Level is such that it only takes a few samples to greatly affect the outcome of a monitoring period. One seemingly benign deviation in the sampling protocol can greatly skew the 90th percentile value. The 50th percentile is much more resilient and, as such, is a good indicator of the relative effectiveness of a CCT.	The 50 th percentile value decreased from 1992 levels by about half after CCT was implemented in 1997. However, the 50 th percentile nearly doubled in 2017.
Greater than 15 µg/L and less than or equal to 25 µg/L	A small deviation within the 15 to 25 ppb range of samples above could put a system out of compliance. By improving the CCT, a system can provide a greater buffer between the 90th percentile values and the AL of 15 ppb, so as to lessen the effects of an unrepresentative sample.	Prior to implementation of CCT (1992), a significant percentage (15%) of the samples were in this range. After many years of no results being in this range, an uptick in results between 15 and 25 ppb began in 2015, continuing to the first half of 2017; and were still elevated thereafter but slightly less than between 2015 and the first half of 2017. This may be indicative that the most significant impact to the pipe scales may have peaked by early 2017, but this cannot be confirmed.

2.3.2 Lead Frequency Distribution – Wanaque Service Area

A frequency distribution analysis was conducted for compliance sampling data collected in 1992, 2002, 2009, 2012, 2015, the two sampling periods in 2017, and the first period in 2018 for the Wanaque service area. Lead sampling rounds were also conducted by the City of Newark in 1998 and 2003; however, samples taken during these periods were concentrated in areas outside of the Wanaque service area.

Figure 2-14 provides an overview of the lead sampling compliance data from the eight (8) sampling events for the Wanaque service area for the different “bins” from less than 5 µg/L to greater than 50 µg/L. **Table 2-3** provides a summary of some statistical parameters based on the lead sampling compliance data, and **Table 2-4** provides an interpretation of the findings of the frequency distribution analyses for the Wanaque service area.

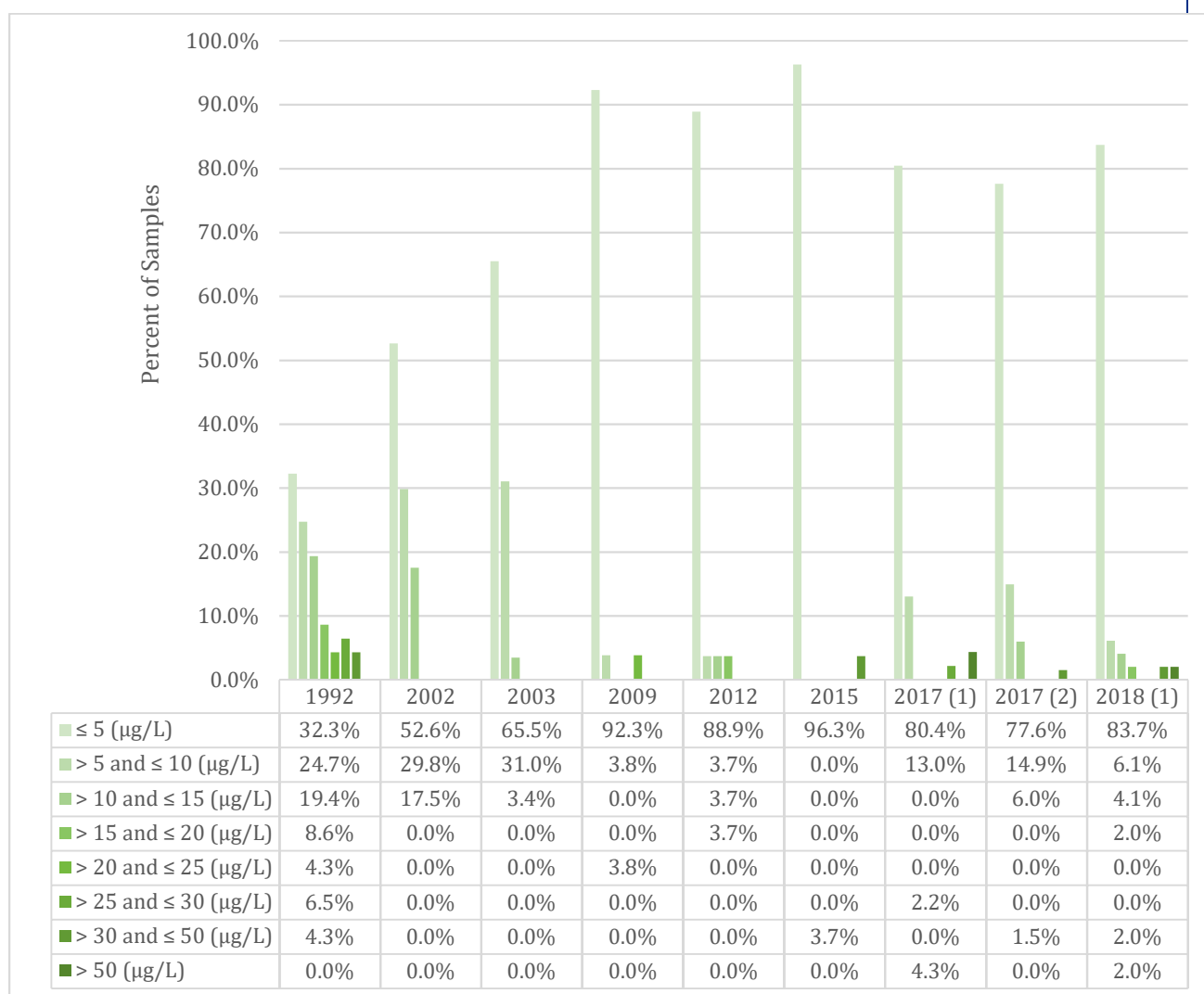


Figure 2-14 – Wanaque Service Area – Lead Sampling Data Percentage Frequency Distribution

Table 2-3 – Summary of Statistical Parameters for Wanaque Lead Sampling Data

Parameter	1992	2002	2003	2009	2012	2015	2017 (1)	2017 (2)	2018 (2)
50th Percentile (µg/L)	6.6	4.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0
75th Percentile(µg/L)	14.2	9.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0
90th Percentile (µg/L)	25.7	11.2	8.4	0.0	6.2	2.0	7.4	8.7	8.7
Number of Samples (n)	93	114	29	26	27	27	46	67	49
Number of Samples >15 µg/L (n)	22	0	0	1	1	1	3	1	3
Percent > 15 & ≤ 25 µg/L	12.9%	0.0%	0.0%	3.8%	3.7%	0.0%	0.0%	0.0%	2.0%
Maximum (µg/L)	49.4	14.9	12.3	24.6	19.0	37.0	84.0	46.1	182.0

Table 2-4 – Wanaque Service Area Frequency Distribution Analysis

Data Category/Bin	What does it tell us?	Newark Wanaque_Pb Results
Overall frequency distribution	Gives a comprehensive picture of sampling results and allows for comparisons over different periods of time.	The Wanaque WTP implemented zinc orthophosphate chemical addition for CCT treatment in the mid 1990s. Between 1992 and 2018, lead sampling results for the Wanaque service area shifted in multiple “bins” (ranges). The 1992 sampling was prior to the CCT treatment improvements. These results point to CCT effectiveness as the cause of a significant decrease in action level beginning in the early 2000s and a shift in the percentage of results into lower bins.
Less than or equal to 5 µg/L	Typically, optimization of a corrosion control treatment is signified by an increased percentage of values that are less than 5 µg/L. When water is treated to be less corrosive, or chemistry is modified to create a stable and insoluble lead compound, overall lead levels will decrease, thereby increasing the percentage of samples with the lowest lead concentrations.	Between 1992 and 2017, there was a large increase in % of samples in this category. Where 1992 saw 32% of samples in this category, 2017 and 2018 sampling saw an increase to an average of 80% between the three sampling pools for lead results less than or equal to 5 ppb. This can again be tied to CCT treatment of zinc orthophosphate. Typically, optimized systems have a majority of sample results (>80%) in the category of <5 ppb.
50th percentile (µg/L)	The nature of the 90th percentile Action Level is such that it only takes a few samples to greatly affect the outcome of a monitoring period. One seemingly benign deviation in the sampling protocol can greatly skew the 90th percentile value. The 50th percentile is much more resilient and, as such, is a good indicator of the relative effectiveness of a CCT.	The 50 th percentile value decreased from 6.6 in 1992 to zero (0) in 2009, and remaining as such ever since indicating effectiveness of the zinc orthophosphate CCT treatment.

Data Category/Bin	What does it tell us?	Newark Wanaque_Pb Results
Greater than 15 µg/L and less than or equal to 25 µg/L	A small deviation within the 15 to 25 µg/L range could put a system out of compliance. By improving the CCT, a system can provide a greater buffer between the 90th percentile values and the AL of 15 µg/L, so as to lessen the effects of an unrepresentative sample.	There was a large decrease in the number of results in this category after the initial sampling round in 1992, which was prior to implementation of CCT. In 2009 and 2012, there was a slight increase in result in this category, which could indicate sampling variability but not definitively. Overall, occurrences of lead levels above the action level decreased significantly indicating the effectiveness of the CCT treatment.

2.3.3 Pequannock Service Area Focus

When separating the LCR compliance sampling data for the Pequannock and Wanaque Gradients, it is clear from the results of the individual lead frequency distribution analyses that a large majority of the lead exceedances have occurred in the Pequannock service area. The frequency of lead exceedances in Pequannock alone has triggered the Lead Action Level exceedances for the City of Newark since the first half of 2017. If the Pequannock and Wanaque Gradients were regulated independently, the Wanaque service area would have been in compliance with the LCR from 2002 to present with 90th percentile values ranging from 0.0 to 11.2 µg/L over that period. Over that same period, the Pequannock 90th percentile values ranged from 9.5 to 36.0 µg/L. In the most recent sampling round, the second half of 2018, the Pequannock 90th percentile based on the verified LCR sampling pool was 39.5 µg/L and the Wanaque 90th percentile based on the verified LCR sampling pool was 4.12 µg/L.

The historic LCR compliance sampling data, as well as the data recently collected as part of this study, show that the current CCT for the Wanaque service area is able to consistently reduce lead levels in the drinking water to below the Lead Action Level.

Due to the determination that the Pequannock system is triggering the Lead Action Level exceedances for the City of Newark, the remainder of this report will focus on the Pequannock service area. This report will evaluate the cause of the elevated lead levels and provide recommendations for reducing lead levels in the Pequannock system.

Since, as a whole, the entire City of Newark is not currently meeting the lead action level due to the Pequannock/Wanaque combined reporting, a more detailed report was requested by NJDEP providing further analysis on the Wanaque Gradient, including sequential sampling and pipe scale analyses. The analysis and any recommendations to optimize CCT in the Wanaque Gradient will be presented in a separate report.

Section 3

Historic Water Quality and Chemical Usage Data

Historic water quality data was obtained from multiple sources provided by NJDEP Drinking Water Watch (as of September 21, 2018), as well as from the City of Newark. The data used for this analysis includes the following:

- City of Newark – Raw Water Supply Quality Analysis for 2016 and 2017. This included monthly averages of pH, temperature, turbidity, color, calcium, alkalinity, hardness and conductivity.
- Optimal Corrosion Control Treatment Recommendations report, prepared by the City of Newark, December 2017.
- Comprehensive Technical Assistance (CTA) Report, prepared by H2M, May 2016.
- Comprehensive Performance Evaluation Pequannock Water Treatment Plant Report, prepared by Aquamize, July 2014.
- Disinfection By-Product Control Bench Scale Investigation, prepared by Carollo Engineers, May 2016
- Daily analysis sheets recorded at the Pequannock WTP lab for delivered and raw water from 2015-2018 (excluding January – October 2017, but including July 2nd, 3rd and 4th of 2017) provided by the City of Newark. This included pH, temperature, chlorine residual, turbidity, color, calcium, alkalinity, hardness and conductivity for delivered water (system point-of-entry (POE)) and pH, temperature, turbidity, color, calcium, alkalinity, hardness and conductivity for the raw water.
- Pequannock WTP monthly chemical usage for 2016 (excluding November), as well as January – March of 2018 provided by the City of Newark. This includes Clarion (potassium aluminum), lime, sodium silicate, chlorine (pre and post) and PACl as minimum, maximum and average dosages in mg/L, as well as total amounts used in pounds per day (lbs/day).
- Monthly averages for raw and delivered water (system POE) data, as well as chemical dosage data, for 2016 and 2017. This includes the turbidity and alkalinity for raw water and the average pH and chlorine residual for delivered water. The monthly average chemical dosage data was provided for Clarion (potassium aluminum), PACl, silicate, chlorine and polymer in mg/L, and lime in lbs/day.
- Total organic carbon (TOC) monthly data for raw and delivered water (recorded from Test House), provided by the City of Newark. This includes October of 2014, May – August and October of 2016, all of 2017 and January – April of 2018 for raw water. January – March, May, November and December of 2017 as well as February and April of 2018 data, were provided for delivered water.

- Pequannock WTP annual average chemical dosing for 2014 provided by the City of Newark.
- Delivered water (system POE) monthly averages for 2016, 2017 and January-March of 2018, provided by the City of Newark. This includes sulfate, magnesium and total dissolved solids (TDS).
- Chemical dosing 2017 monthly chemical usage (lbs), yearly total usage and yearly average, provided by the City of Newark. This includes alum/polymer, chlorine, PACl, lime, polymer and silicate.
- Raw water and delivered water (system POE) monthly turbidity averages for 2017, provided by the City of Newark.
- Raw water and delivered water (system POE) data , as well as chemical dosage data, for the first half of September 2018, provided by the City of Newark. This included average pH, temperature, alkalinity and calcium for raw water, and pH, temperature, chlorine residual, alkalinity and calcium sampled at Test House.
- Source Water Monitoring Program data, provided by the City of Newark for September 2015, March, April, May, June and September of 2016, and April of 2017. This included a sample from each month for temperature, dissolved oxygen (DO), pH, conductivity, color, turbidity, alkalinity, hardness and TOC.
- Data from NJDEP Water Watch which was mainly used to fill in gaps in the City of Newark's data for raw and delivered water (system POE), when available. In addition, NJDEP Water Watch was used to collect data at the other sampling sites, such as the Cedar Grove Reservoir, Valley Road, Belleville Reservoir and the distribution system.
- Valley Road Rechlorination Station daily chlorine residual and pH from 2005 to September 2018, and a few data points prior to 2005.

3.1 Recent Water Quality Data

Recent data obtained from Newark and NJDEP's Water Watch were used for the purpose of understanding the source and finished water characteristics of the Pequannock WTP as related to corrosion control. The data used are summarized in **Table 3-1**.

Table 3-1 – Key Water Quality Parameters for Corrosion Control Evaluation

Parameter	Water Type	Duration	Frequency
Temperature	Source/Finished	January 2015 – April 2018	Daily, excluding January – October 2017
pH	Source/Finished/ Valley Road Rechlorination Point-of-Entry (POE)	January 2015 – August 2018 (used for current averages) February 1992 – August 2018 (used for historic trends) Valley Road: January 2005 to August 2018 (used for distribution system POE)	2015-2018: Daily, excluding January – October 2017, bi- weekly after April 2018 for delivered water (POE) 2005-2018 historic: a few samples per year; sporadic Valley Road: daily
Alkalinity	Source/Finished	January 2015 – August 2018	Daily, excluding January – October 2017, bi-weekly after April 2018 for delivered water (POE)
Calcium	Source	January 2015 – April 2018	Daily, excluding January – October 2017
Chlorine Residual	Valley Road Rechlorination – Post-Chlorine POE	Valley Road: January 2005 to August 2018	Daily
Magnesium	Source	January 2016 – February 2018	Monthly averages, excluding September 2016
Total Dissolved Solids	Source	January 2016 – March 2018	Monthly averages
Chloride	Source	June 1994 – October 2017	16 samples
Silica	Finished	June 2009 – August 2018	5 samples in 2009, bi weekly starting July 2016
Sulfate	Finished	June 1994 – March 2018	22 samples from NJDEP Water Watch, monthly averages from the City of Newark for January 2016 – February 2018 (excluding September 2016)

Because water systems experience variability in water quality throughout the year, as would be expected with a northeast reservoir supply, it is important to evaluate the full range of water quality expected. Four (4) seasonal scenarios were developed based on seasonal water quality fluctuations in the Pequannock Reservoir source water. The seasonal scenarios are as follows:

- Warm temperature conditions(June 19th – September 18th) – Summer
- Cooling period (September 19th – December 18th) – Fall
- Cold temperature conditions (December 19th – March 18th) – Winter
- Warming Period (March 19th – June 18th) – Spring

Figures 3-1 through 3-10 illustrate source and delivered water quality (where available), as well as seasonal trends, for temperature, pH, alkalinity, calcium, and magnesium. **Figure 3-11**

provides the amount of silica residual present in the delivered water in comparison to the amount of sodium silicate being dosed into the water, in mg/L as SiO₂. **Figure 3-12** presents the delivered water levels of chloride and sulfate from the available data. As evident from the figures, daily data from January through October 2017 are missing from Newark's records for alkalinity and calcium. The following remarks on data analysis are noted:

- The seasonal variability in source water temperature is evident, as color-coded and labeled in **Figures 3-1** and **3-2**. The source water temperature, over the last four years, from 2015 to 2018, generally ranged from 5 degrees Celsius in winter to 25 degrees Celsius in the summer.
- Source water pH ranges from 5.7 to 7.5 as shown in orange in **Figure 3-3**. Finished water pH leaving the Pequannock WTP over the last four years, from 2015 to 2018, has shown variability ranging from 6.0 to 8.8, as shown in blue. Over the last 2 years, finished water pH has tended to range from 6.5-7.5. Longer term pH trends are described in Section 3.3.1.
- Alkalinity in the source water generally ranged between 10 and 35 mg/L as CaCO₃ over the last four years, from 2015 to 2018, as shown in **Figures 3-5** and **3-6**, depending on the season. Alkalinity increases as the water temperature increases and decreases as the water cools.
- Calcium levels in the source water have a generally increasing trend from the cold to warm seasons, as shown in **Figures 3-7** and **3-8**. Calcium concentrations in the source water are generally between 6 and 14 mg/L as Ca²⁺ and increase in the finished water to between 10 and 18 mg/L as Ca⁺, due to the addition of lime.
- Magnesium in the delivered water ranged from 3.8 mg/L as Mg to 5 mg/L as Mg as shown in **Figures 3-9** and **3-10**. No obvious seasonal trends are present. The raw magnesium levels are assumed to be similar to the levels in the delivered water, as no chemicals with significant amounts of magnesium are added at the plant.
- Silica concentrations measured at the plant finished water (Test House) ranged from 5.7 to 12.0 mg/L as SiO₂ between December 2015 and August 2018 as shown in **Figure 3-11**. The sodium silicate dosed at the Pequannock WTP ranged from 10.1 – 14.1 mg/L as sodium silicate, or 2.9 to 4.1 mg/L as SiO₂. It is reported that the silica concentration in the raw water is approximately 4.0 mg/L as SiO₂ (Newark, 1994).
- Chloride in the delivered water ranged from 25 mg/L as Cl to 45 mg/L as Cl from 1994 to 2017 as shown in **Figure 3-12**. Polyaluminum chloride (PACl) is added at the Pequannock WTP for coagulation, which contributes to increased chloride levels. As expected due to runoff from road salts, chloride levels were higher in the winter months than in other seasons. The overall annual average was 33.1 mg/L as Cl.
- Sulfate in the delivered water ranged from 8.1 mg/L as SO₄ to 16.3 mg/L as SO₄²⁻ with an average of 11.4 mg/L as SO₄ as shown in **Figure 3-12**. The Pequannock WTP adds aluminum sulfate (alum) as one of their coagulants, which contributes to the sulfate levels.

Figure 3-1 Historic Pequannock WTP Temperature - Influent and Delivered Water

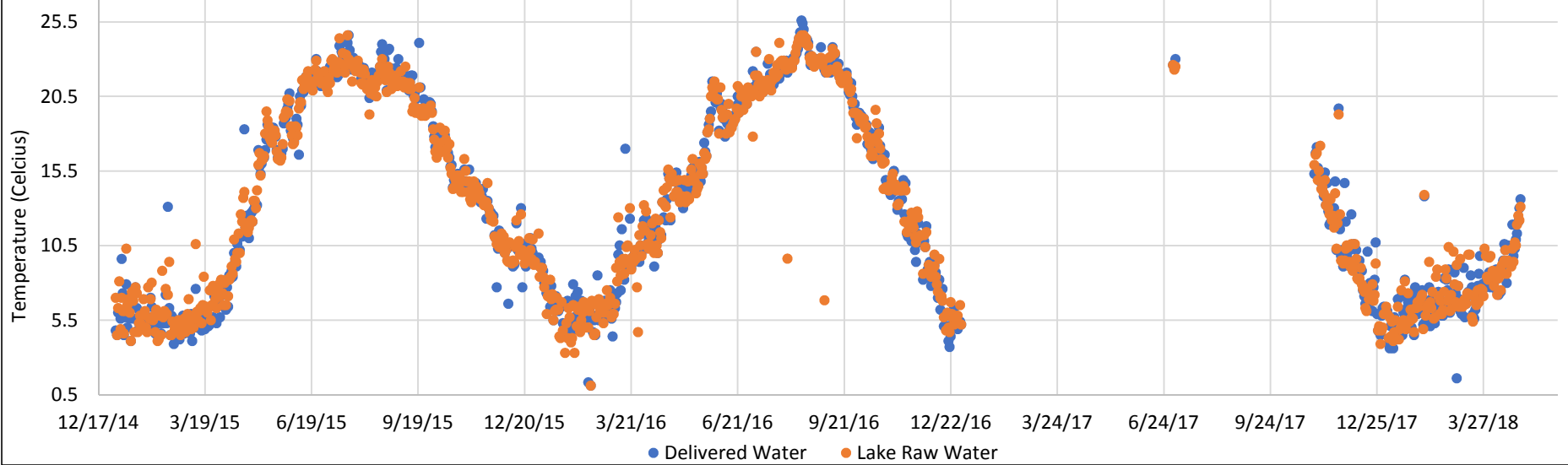


Figure 3-2 Historic Pequannock WTP Temperature - Influent Water Seasonal Trends

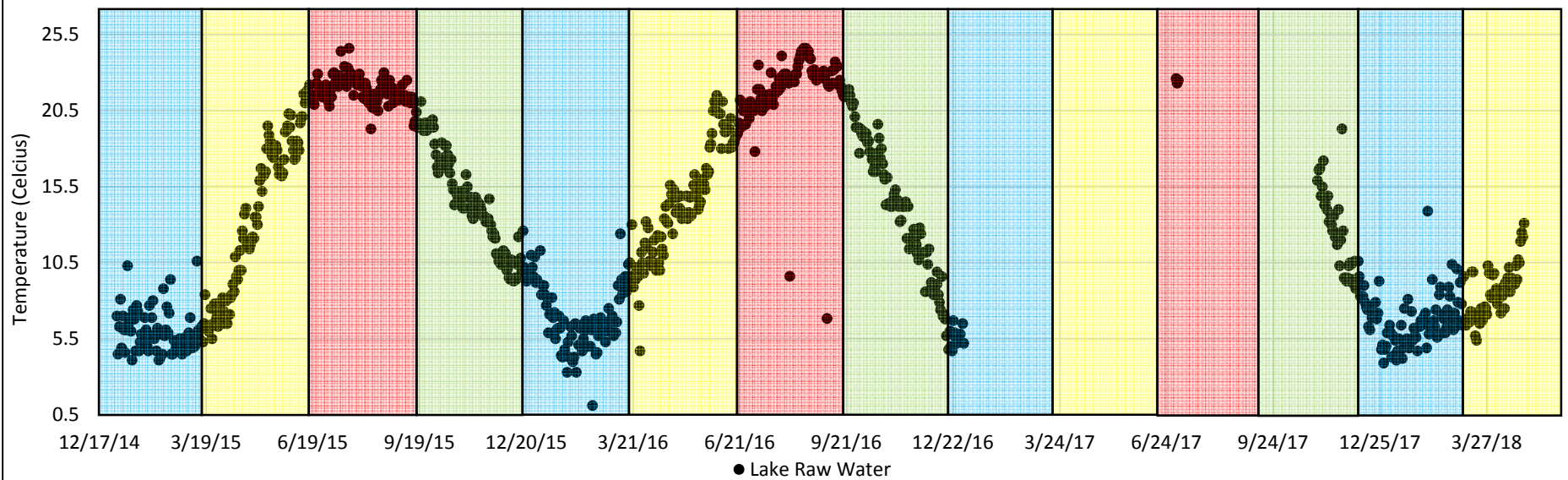


Figure 3-3 - Historic Pequannock WTP pH - Influent and Delivered Water

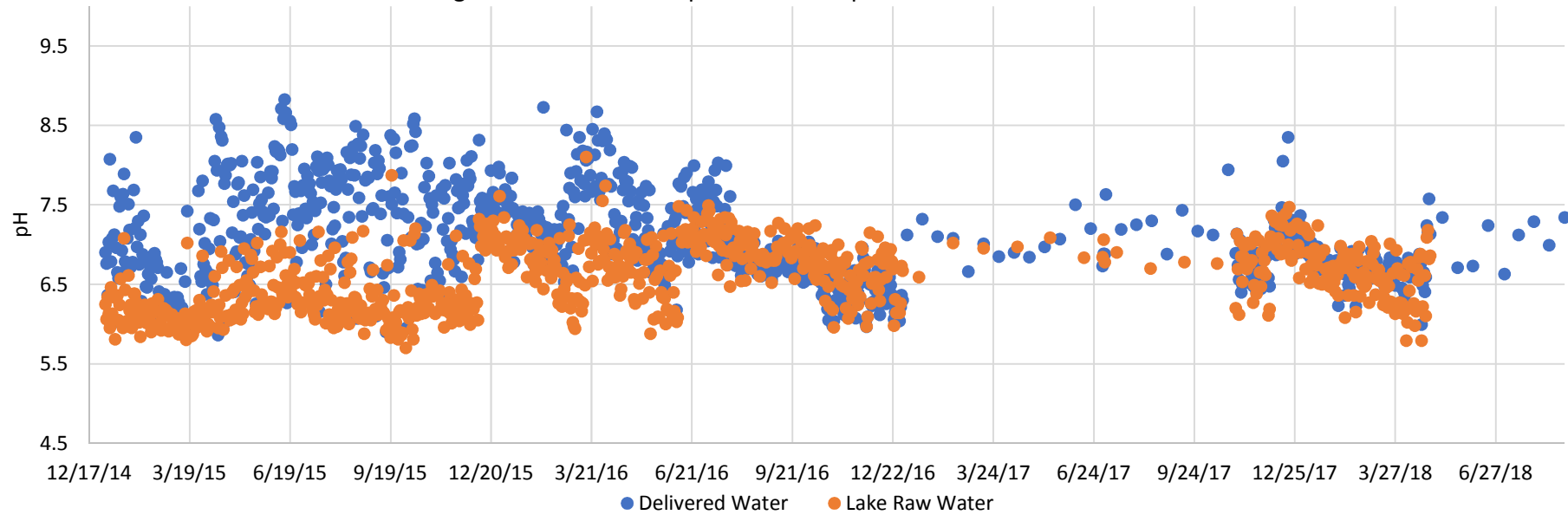
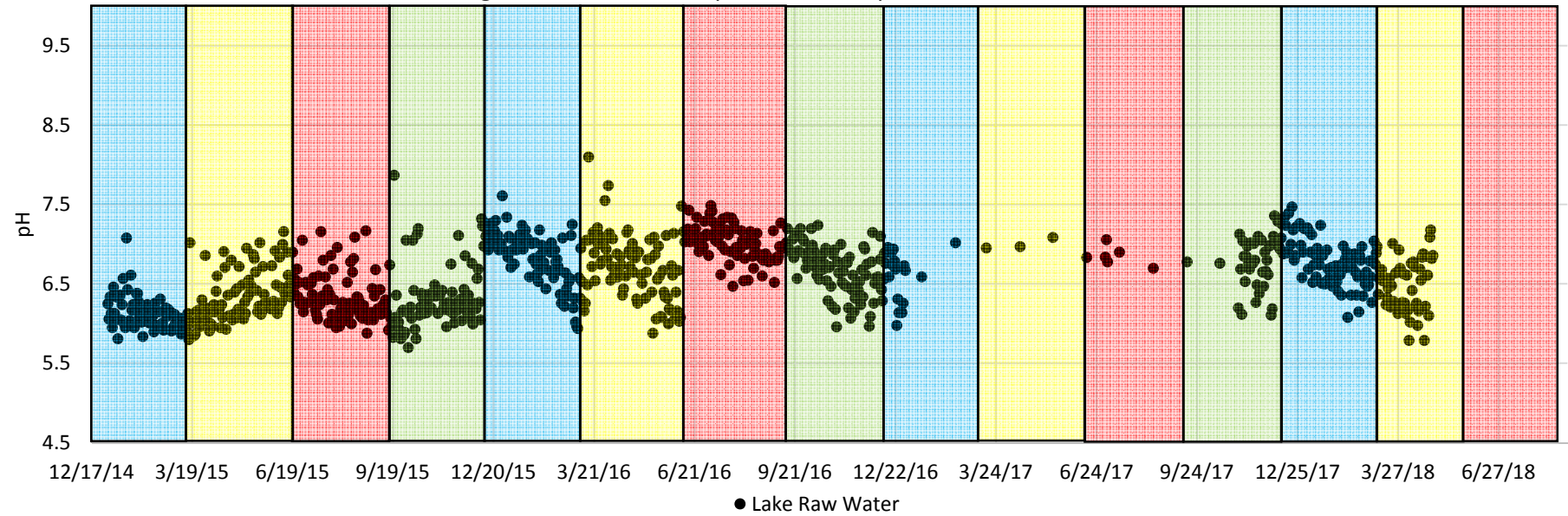


Figure 3-4 - Historic Pequannock WTP pH - Influent Water Seasonal Trends



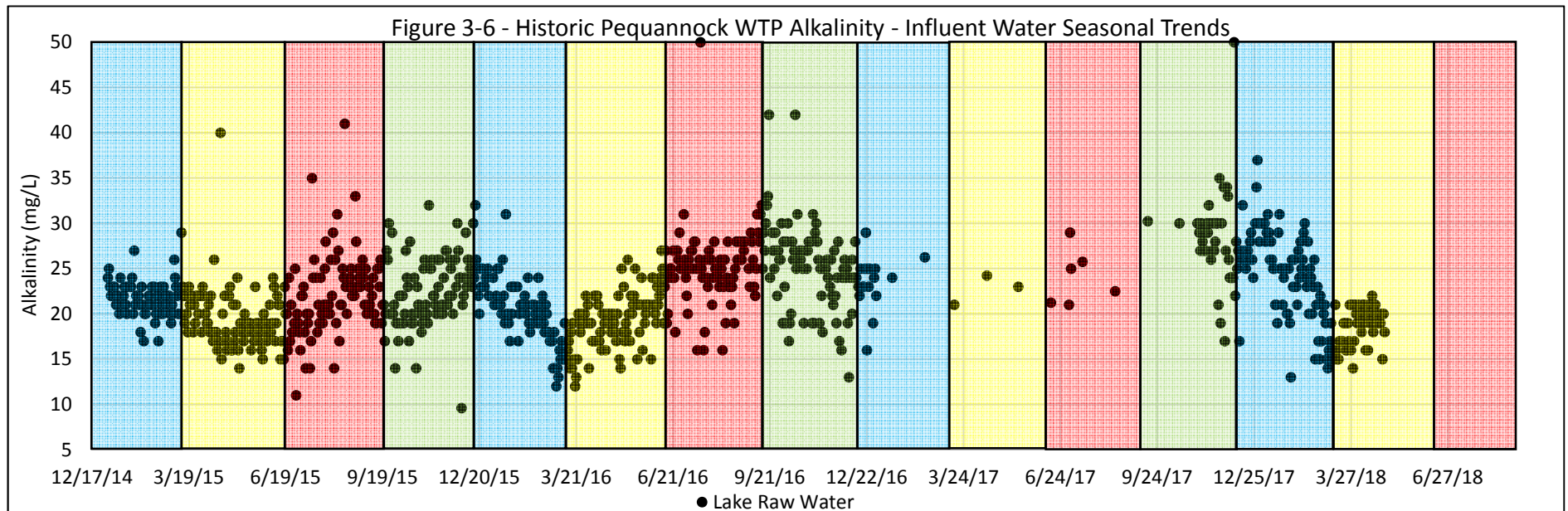
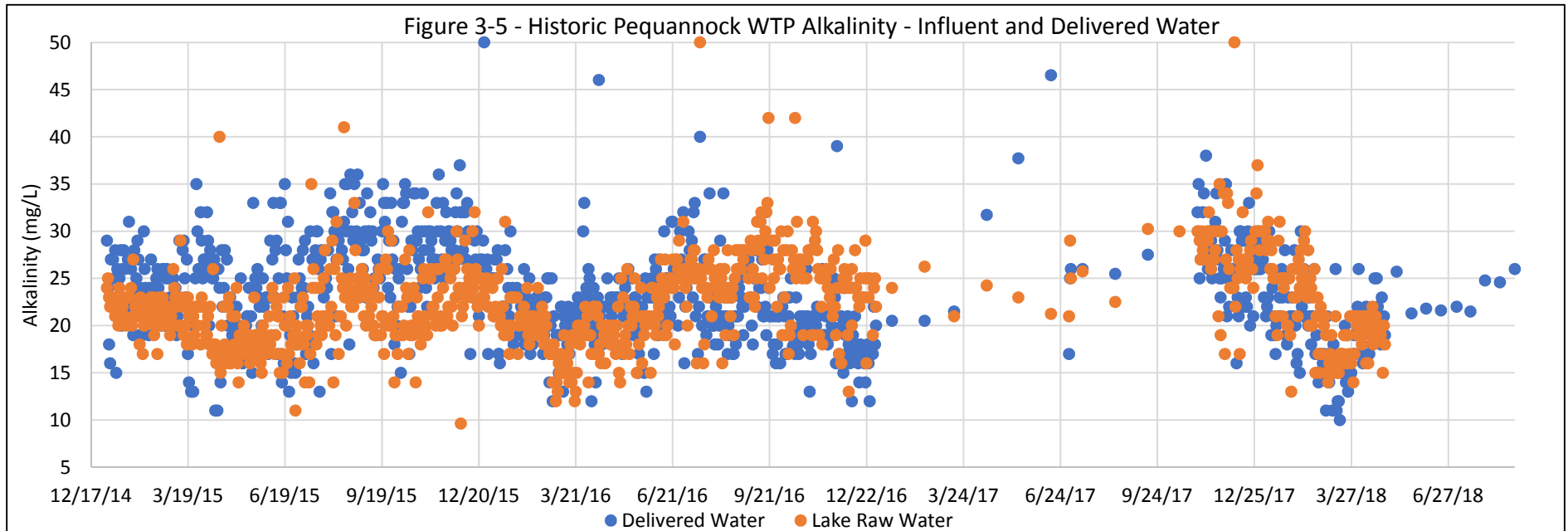


Figure 3-7 - Historic Pequannock WTP Calcium - Influent and Delivered Water

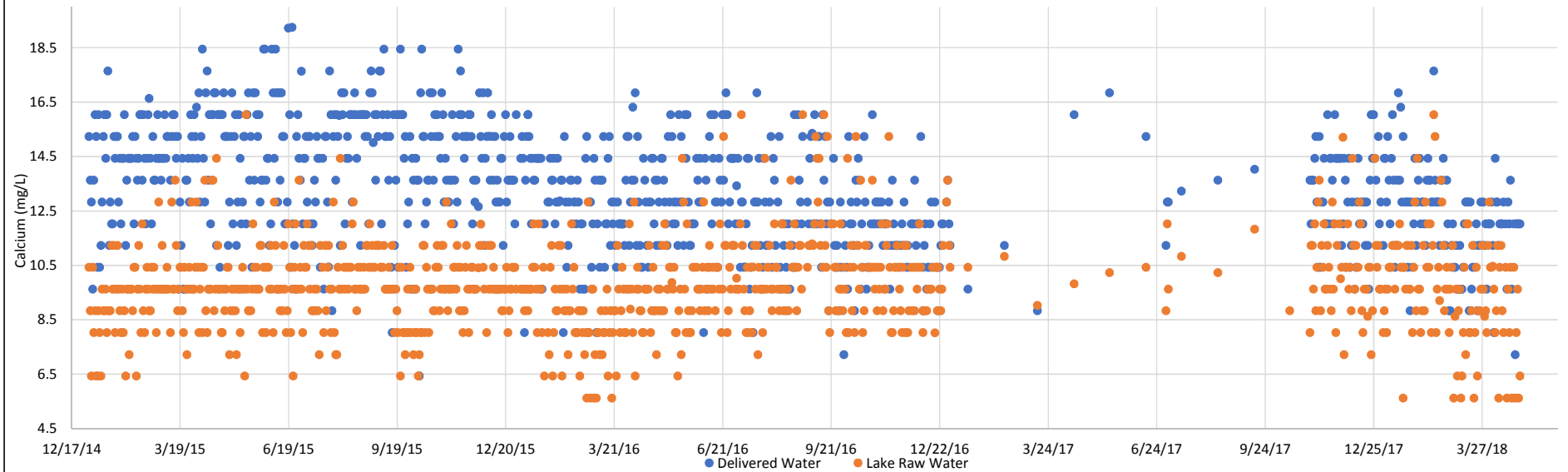
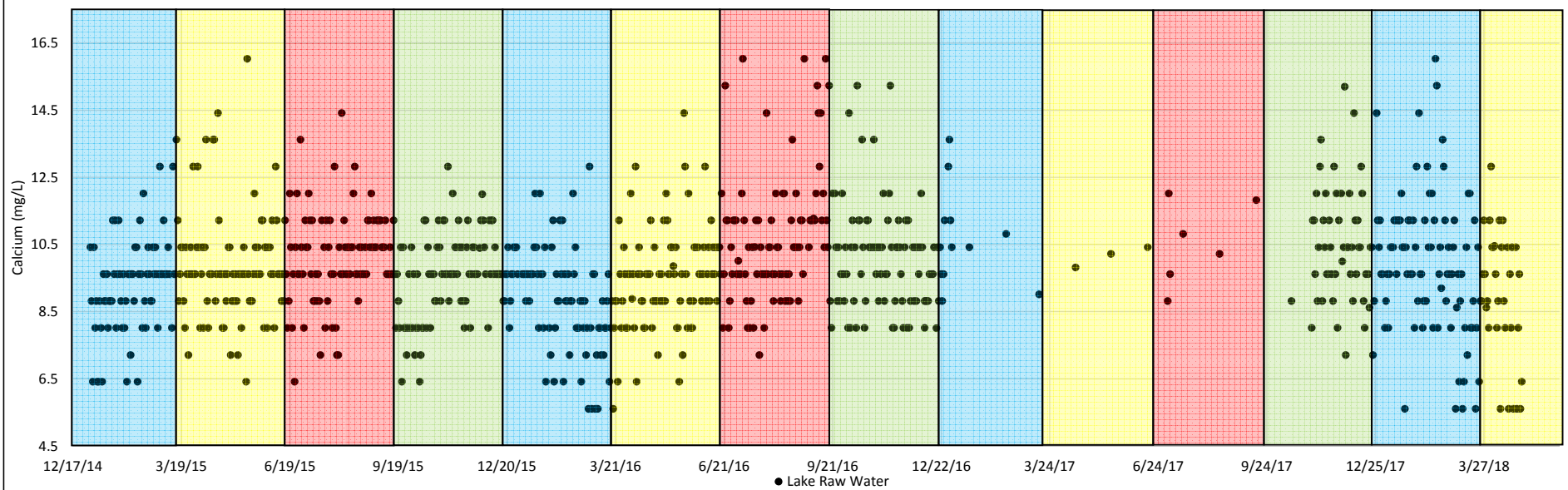
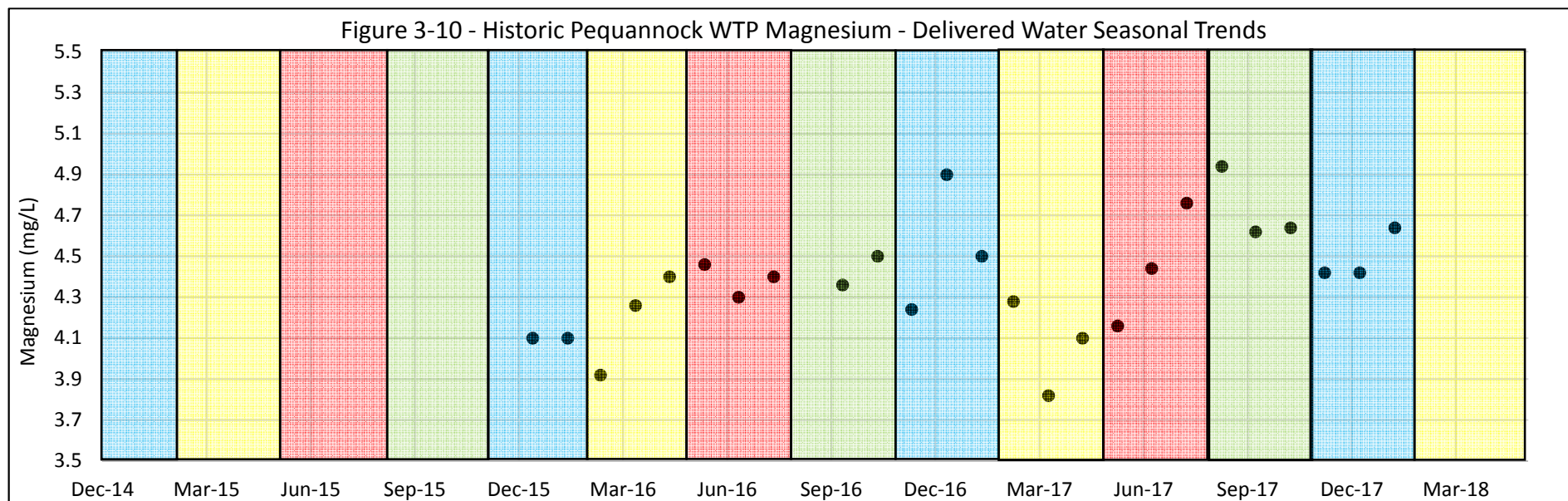
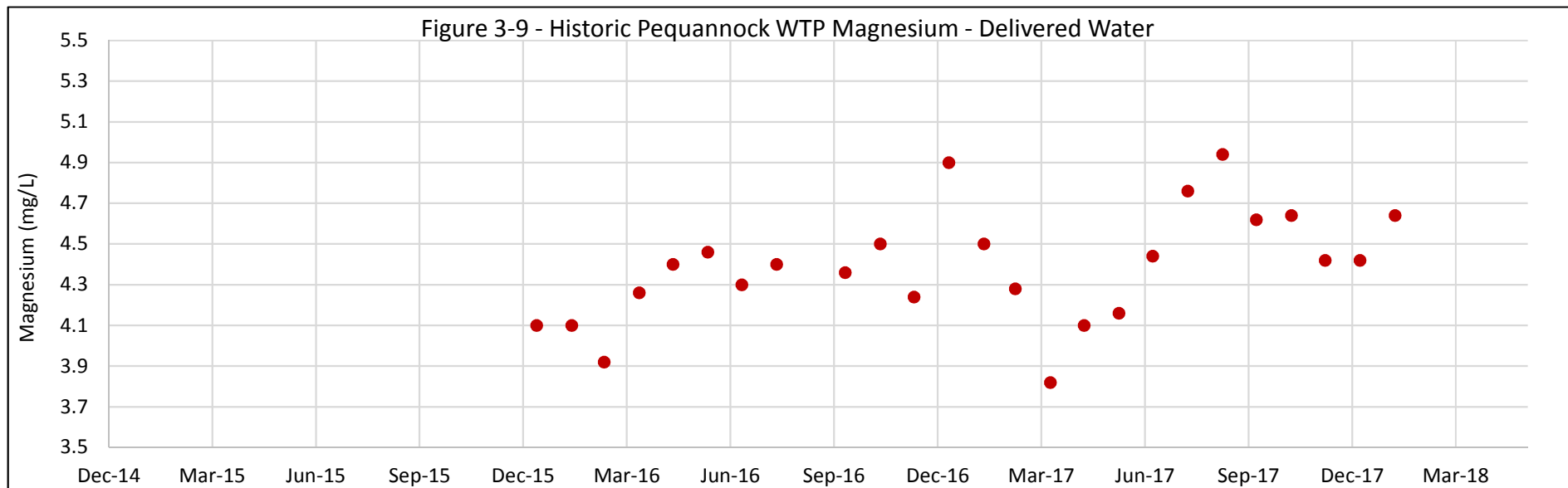


Figure 3-8 - Historic Pequannock WTP Calcium - Influent Water Seasonal Trends





Section 3 • Historic Water Quality and Chemical Usage Data

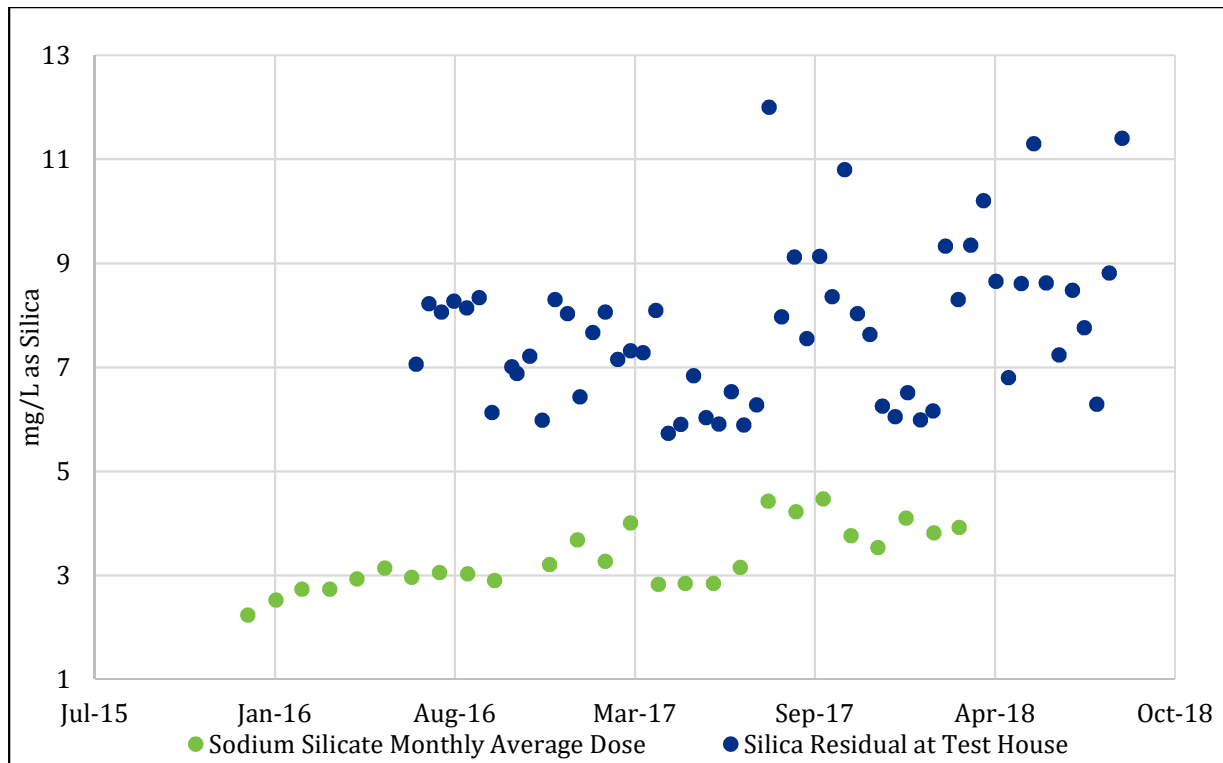


Figure 3-11 – Historic Pequannock WTP Silica – Dose vs. Delivered Water

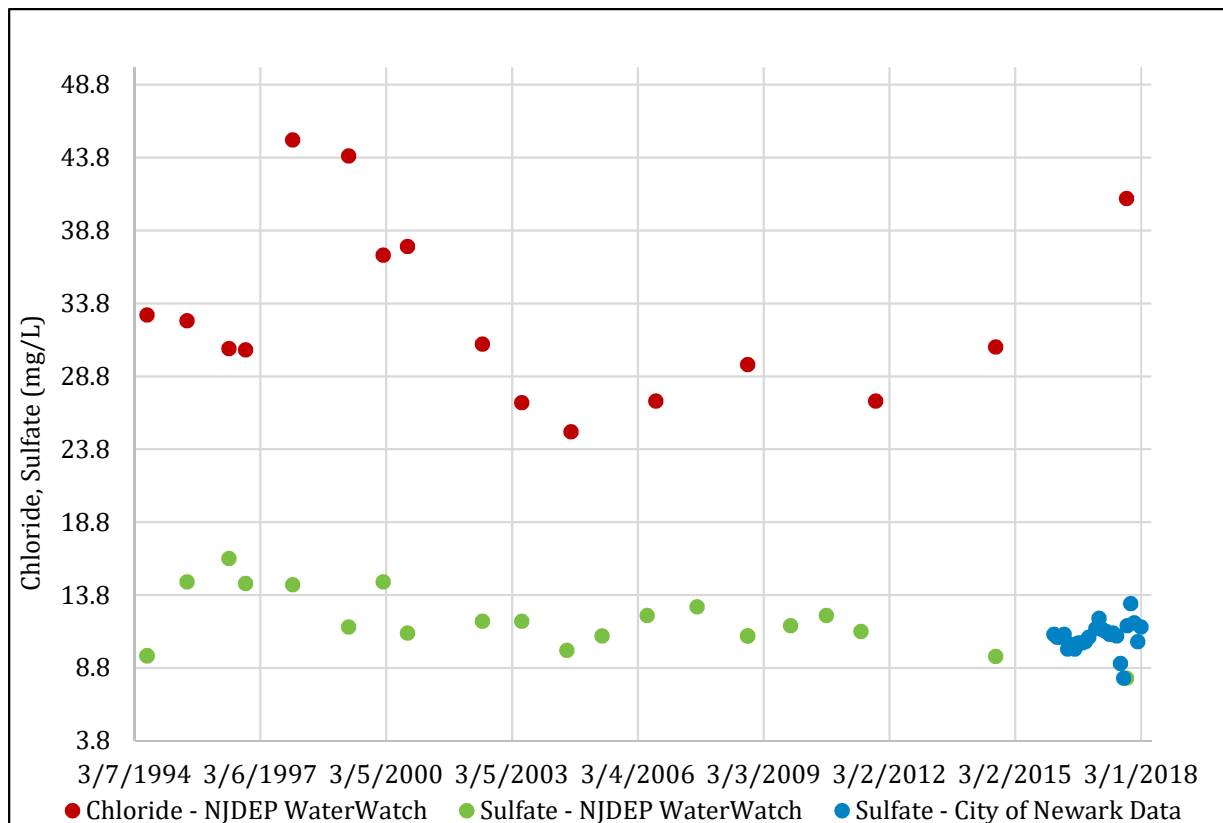


Figure 3-12 – Historic Pequannock WTP Chloride and Sulfate – Delivered Water

3.1.1 Chloride-to-Sulfate Mass Ratio

Galvanic corrosion on lead-copper joints can be accelerated and cause a release of lead with a higher chloride to sulfate mass ratio (CSMR). CSMR is calculated by dividing the average chloride concentration by the average sulfate concentration (Nguyen, Stone, Clark, & Edwards, 2010). The literature reports a “threshold” CSMR value of 0.5, above which galvanic corrosion of lead solder on copper piping can increase. The greatest concerns, however, are utilities with lead solder joints that change their water chemistry to increase CSMR from below 0.5 to above 0.5 as indicated in the Water Research Foundation (WRF) 4088 Study (Nguyen, Stone, Clark, & Edwards, 2010).

The researchers in the WRF study observed that in waters with chloride to sulfate equal to or less than 0.5, very low corrosion rates were observed. High chloride relative to sulfate, yielding CSMRs above 0.5, tended to increase galvanic corrosion of lead solder connected to copper pipe. They also observed, statistically, that as relative concentrations of chloride to sulfate increased in the water supply, the 90th percentile lead concentration generally increased. In their bench-scale experiments, waters with high CSMR were consistently more aggressive in increasing lead leaching from solder galvanically connected to copper.

Based on an average chloride concentration of 33.1 mg/L and an average sulfate ratio of 11.4 mg/L, Newark’s average CSMR is 2.9. Although Newark’s CSMR is above the 0.5 threshold, there are many systems that operate with similar or higher CSMRs that do not have high lead levels or Action Level exceedances. The likely reason for this is that much of the solder exposed to the water may have been released at extremely low rates over decades. The WRF research focused on simulating release of lead from solder that was abruptly subjected to high CSMR water. This is corroborated by full-scale experience where the CSMR changed abruptly due to a process or water quality change (e.g., systems changing from alum to PACl or alum to ferric chloride). In these cases, the “baseline” condition was a relatively low CSMR (often times greater than 0.5), and the operational change caused a sudden increase in CSMR, which contributed to lead release and spikes in tap water sampling results (Nguyen, Stone, Clark, & Edwards, 2010).

Newark doses both alum and PACl as coagulants at their Pequannock WTP and has had a consistent dosing ratio in recent history. The data for chloride and sulfate have shown consistent levels within a narrow range since the beginning of the available data set in 1994, as shown in **Table 3-2**. The galvanic corrosion in lead solder joints on copper piping due to the elevated CSMR in Newark’s system has likely occurred over many years at a slow rate, since no drastic change in the CSMR is apparent in at least the last 24 years.

Table 3-2 – Calculated CSMR Values from Available Chloride and Sulfate Data

Date	Chloride as Cl	Sulfate as SO ₄	Calculated CSMR Value
6/23/1994	33	9.64	3.42
6/6/1995	32.6	14.7	2.22
6/4/1996	30.7	16.3	1.88
10/28/1996	30.6	14.6	2.10
12/12/1997	45	14.5	3.10
4/14/1999	43.9	11.6	3.78
2/7/2000	37.1	14.7	3.31
9/7/2000	37.7	11.2	3.37

Date	Chloride as Cl	Sulfate as SO ₄	Calculated CMSR Value
6/21/2002	31	12	2.58
5/30/2003	27	12	2.25
10/16/2008	29.6	11	2.69
9/11/2014	30.8	9.58	3.22
10/25/2017	41	8.09 ^[1]	5.07 ^[1]

^[1] Sulfate data from October 25, 2017 appears to be an anomaly and too low, resulting in a high apparent CMSR. Additional data will be reviewed to determine if this value is accurate.

3.2 Chemical Usage Observations

Chemical usage data at the Pequannock WTP was obtained from the City of Newark and analyzed for dosage trends that may affect the seasonal water quality variations for pH, alkalinity, calcium, and other corrosion-related parameters as discussed in Section 3.1. The data obtained includes monthly averages from January 2016 – March 2018, excluding 2017, for the following chemicals:

- Clarion – Potassium alum
- Lime (100% Hydrated Lime)
- Sodium Silicate
- Polyaluminum chloride (PACl)
- Chlorine gas

Figures 3-13 and 3-14 show the chemical dosage data for Clarion, lime, sodium silicate, and PACl, and seasonal trends where present. The data was also compared with 2014 data presented in the CTA report. The following remarks on data analysis for chemical usage are noted:

- No significant seasonal variation was observed in Clarion (alum) dosage, which ranged from 8.9 mg/L to 9.9 mg/L. The average dose of the data provided for Clarion was 9.5 mg/L. Generally, the average Clarion dose is consistent throughout the year and consistent with the average dose in 2014 which was 9.2 mg/L.
- No significant seasonal variation was observed in lime dosage, which ranged from 2.6 mg/L to 4.2 mg/L. The average dose of the data provided for lime was 3.1 mg/L. According to the CTA, the average lime dose in 2014 was 4.5 mg/L.
- No significant seasonal variation was observed in the sodium silicate dosage, which ranged from 9 to 11.0 mg/L as sodium silicate. The average dose of the data provided for sodium silicate was 11.4 mg/L as sodium silicate. Generally, the sodium silicate dose has been maintained around this average value, but it was noted that starting July 24, 2017, the sodium silicate dose was reportedly increased to 12-15 mg/L as sodium silicate. In comparison with the CTA, the average sodium silicate dose in 2014 was 8.3 mg/L as sodium silicate.

Figure 3-13 - Historic Pequannock WTP Chemical Dosages - Clarion, Lime, Sodium Silicate, PACI

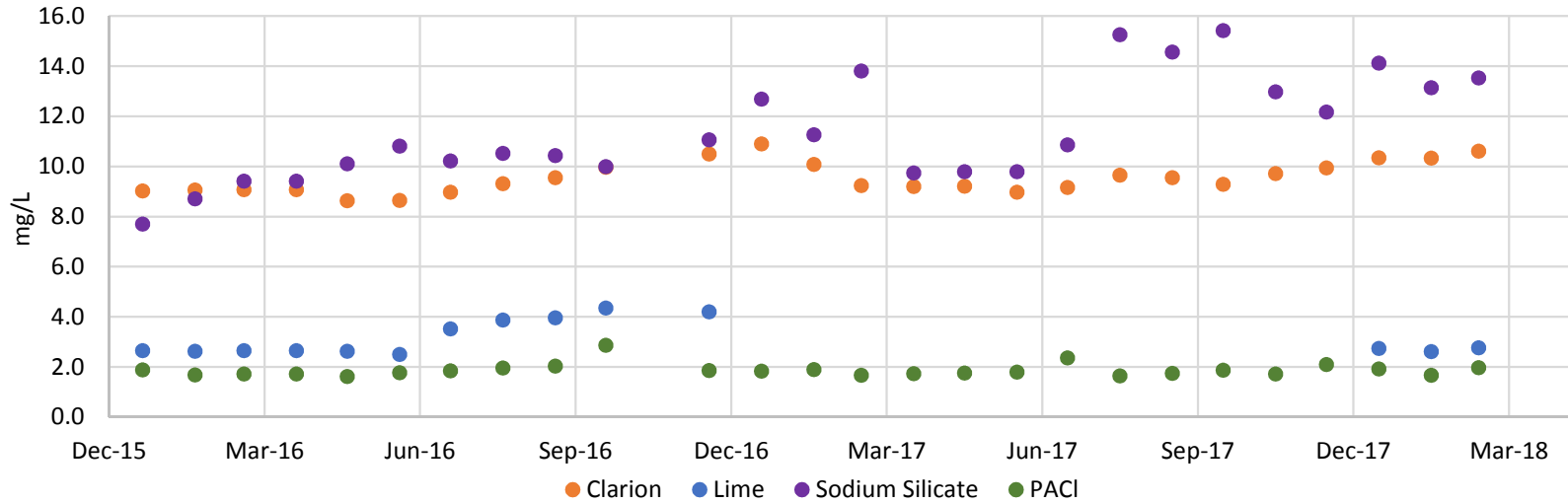
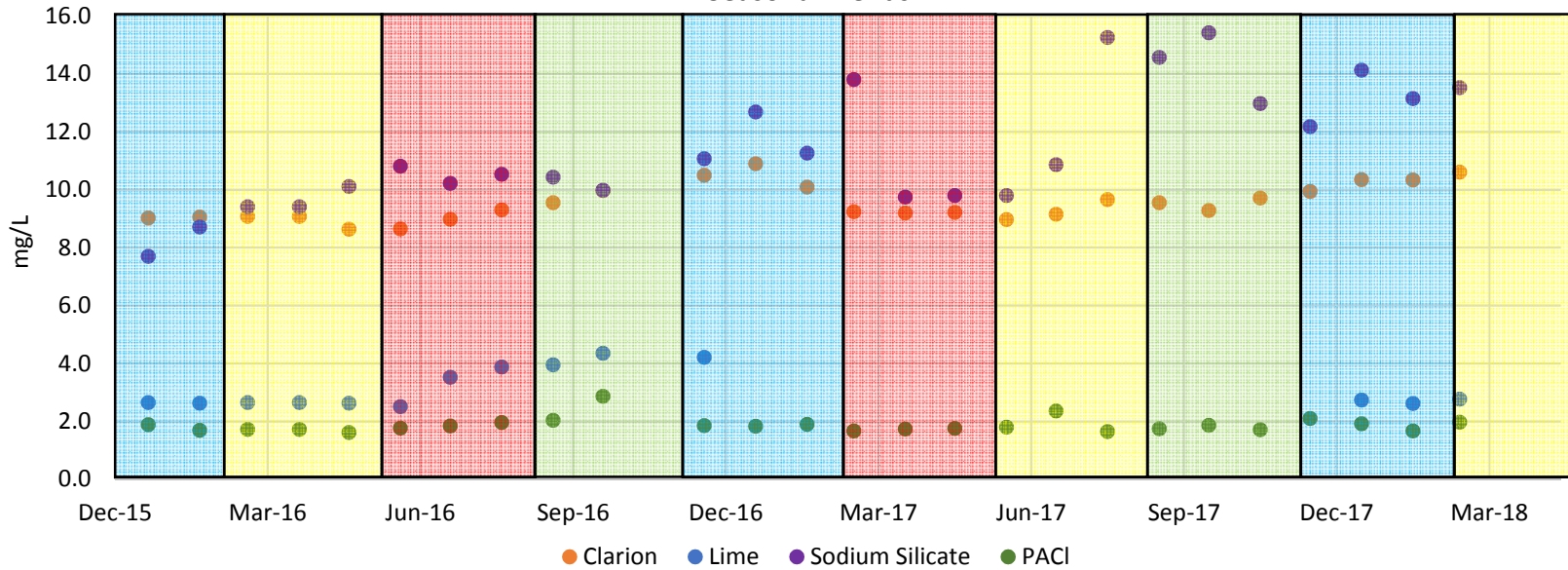


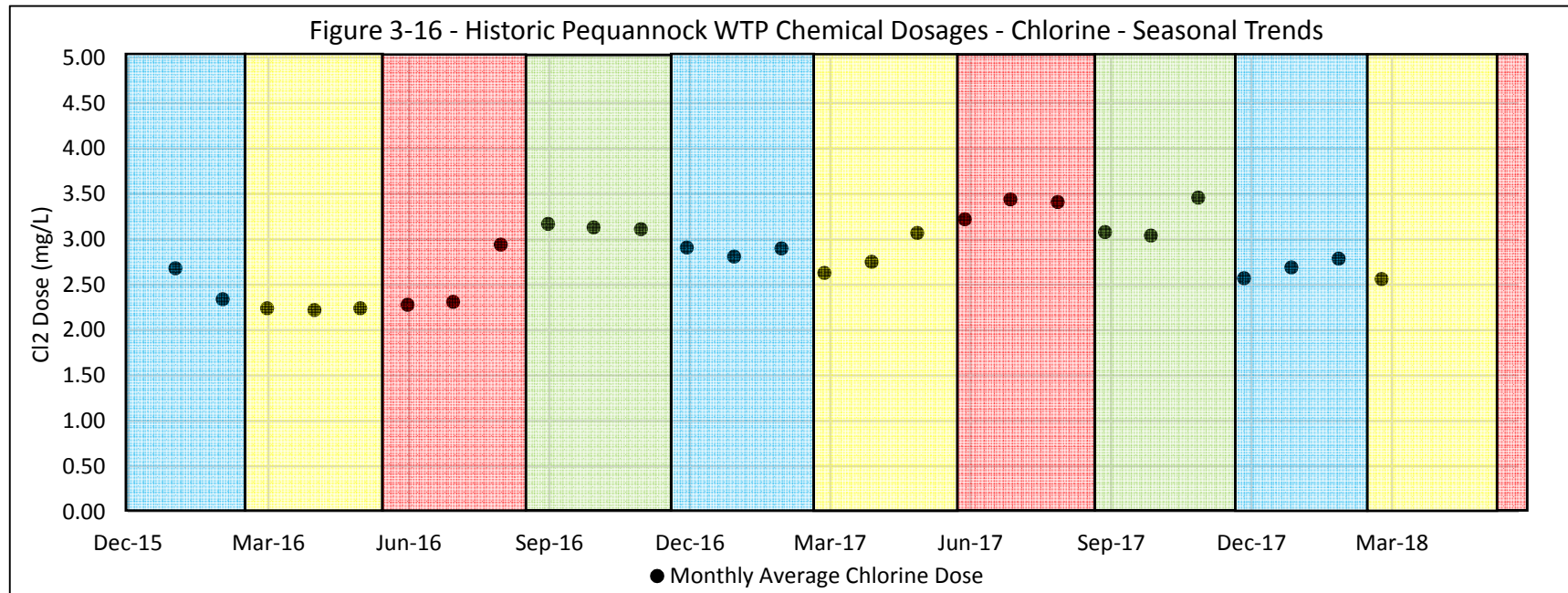
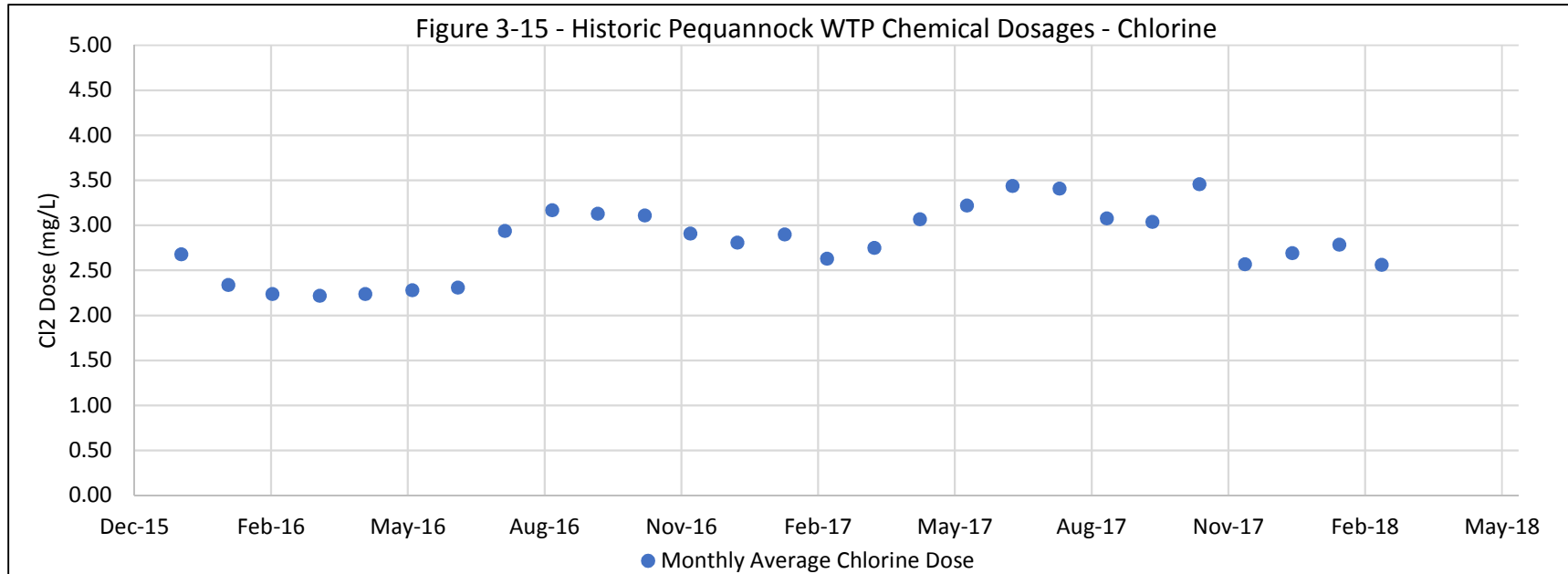
Figure 3-14 - Historic Pequannock WTP Chemical Dosages - Clarion, Lime, Sodium Silicate, PACI - Seasonal Trends



- No significant seasonal variation was observed in the PACl dosage, which ranged from 1.7 mg/L to 2.5 mg/L. The average dose of the data provided for PACl was 1.9 mg/L. Generally, the average PACl dose is consistent throughout the year and consistent with the average dose in 2014 which was 1.6 mg/L.

Figures 3-15 and 3-16 show the chemical dosage data and the seasonal trends for chlorine, from January 2016 – March 2018. January – March 2018 monthly dose averages were calculated from the use of chemical (lbs/month) and the 2017 daily flow to produce average seasonal data. The following remarks are noted from the data analysis for chlorine usage:

- The chlorine dosage ranges from 2.5 to 4.0 mg/L. The average dose of the data provided for chlorine is 3.0 mg/L (total of pre and post-chlorine addition). Generally, the chlorine dose has been maintained in this range. An increase in dosage in the summer months is observed, as expected due to warmer temperatures and chlorine's greater reactivity.
- The data does not include the sodium hypochlorite that is added at the Valley Road Rechlorination Station. The chlorine residual data from the addition of sodium hypochlorite at the Valley Road Rechlorination Station are included in Section 3.3.2.



3.3 Long-Term Water Quality Trends

This section reviews some of the longer-term trends of water quality parameters in Newark's system that have been variable over time and are known to have an impact on corrosion and corrosion control.

3.3.1 Historic pH – Pequannock WTP and Valley Road Rechlorination Station

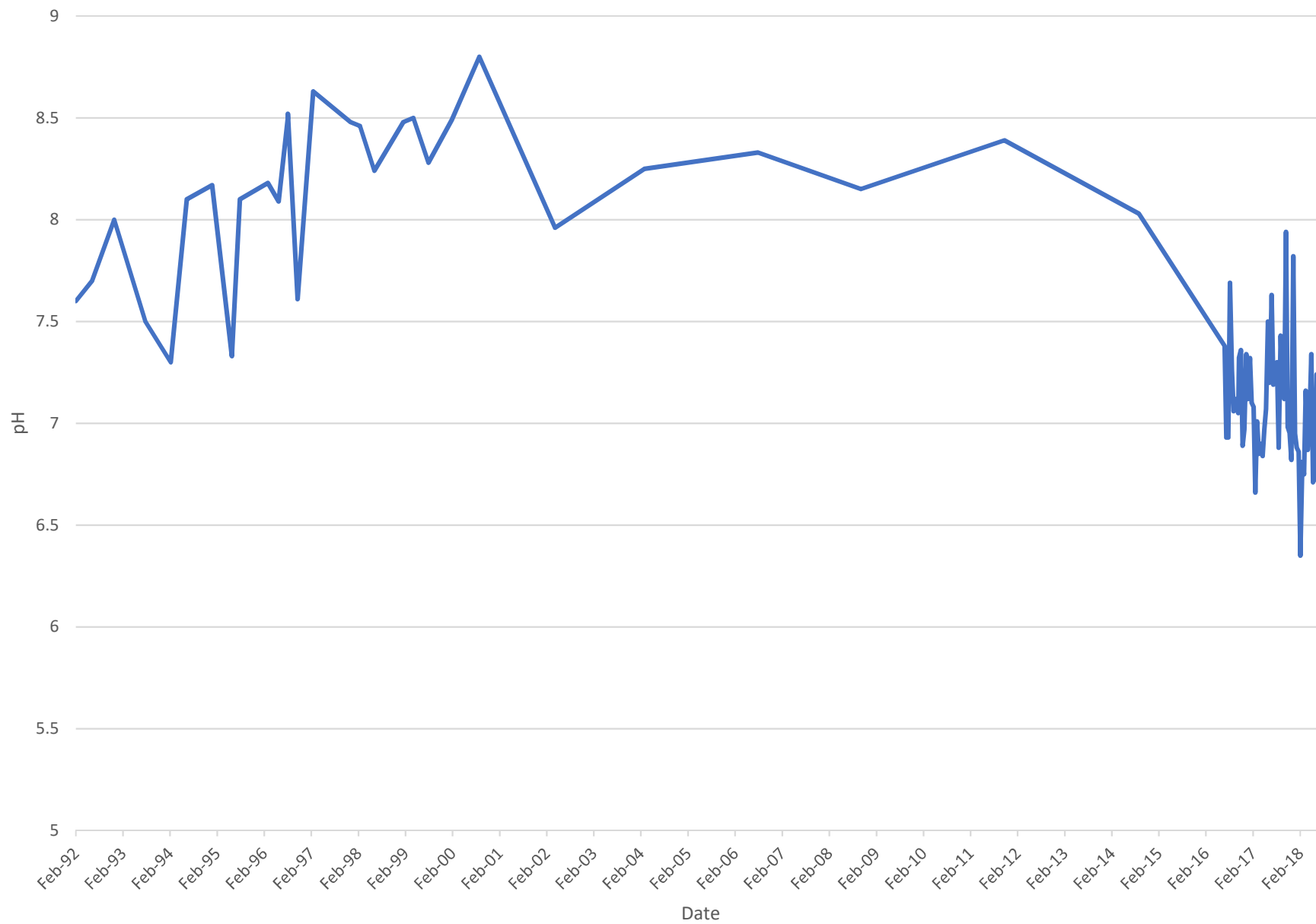
Historic pH data leaving the Pequannock WTP (at the "Test House") was available from February 1992 to September 2018 on Water Watch. **Figure 3-17** indicates that after the CCT study was performed in 1994 (See Section 2.1.1), Newark slowly raised its delivered water pH to around 8.5 from 1996 through 2002. In 2002, pH levels fell slightly to approximately 8.0 to 8.3. Although there are not many data points available, it appears that Newark generally maintained this level between 2002 and 2012. In 2013, pH levels fell to below 8.0 and have not been above 8.0 since. In the last 4 years, the average pH of the Pequannock WTP finished water was 7.1 based on data provided at the Test House. The averages over the last four recent years were as follows:

- 2015 – average pH of 7.26
- 2016 – average pH of 7.04
- 2017 – average pH of 7.00
- 2018 – average pH of 6.72 (January through August 2018)

The reduction in pH generally correlates to when monitoring for the Stage 2 Disinfectants and Disinfection Byproducts (DBPs) Rule commenced. Large systems were required to start monitoring and reporting DBPs using the Location Running Annual Average (LRAA) in 2012. It appears that Newark may have started decreasing pH around this time in an effort to meet the DBP regulatory requirements. Historic data was also available between 2005 and 2018 for the pH leaving the Valley Road Rechlorination Station before it enters the distribution system. **Figure 3-18** provides the pH data leaving the Rechlorination station during this period. The pH values at the Rechlorination Station tend to vary because of the low alkalinity (low buffer intensity), and are less than the pH of the Pequannock WTP finished water. Based on **Figure 3-18**, the average pH ranged from 7.6 to 8.0 from 2005 to 2012, with a few sustained periods above pH 8.0. After 2012, pH dropped to an average range of 7.5 to 7.7. pH increased to above 8.0 for a few months in 2015, and then decreased again in 2016, 2017 and 2018 to the current average around 7.0. A drop in pH starting in 2016 is apparent in both the Pequannock WTP delivered water (system POE) data as shown in **Figure 3-17** and the Valley Road Rechlorination Station data as shown in **Figure 3-18**.

Additional data points were provided for years prior to the silicate addition by Newark. In 1984, pH generally ranged between 7.8 and 8.0. In 1989-1990, pH ranged between 7.1 and 7.6.

Figure 3-17 – Historic Pequannock WTP Delivered Water pH



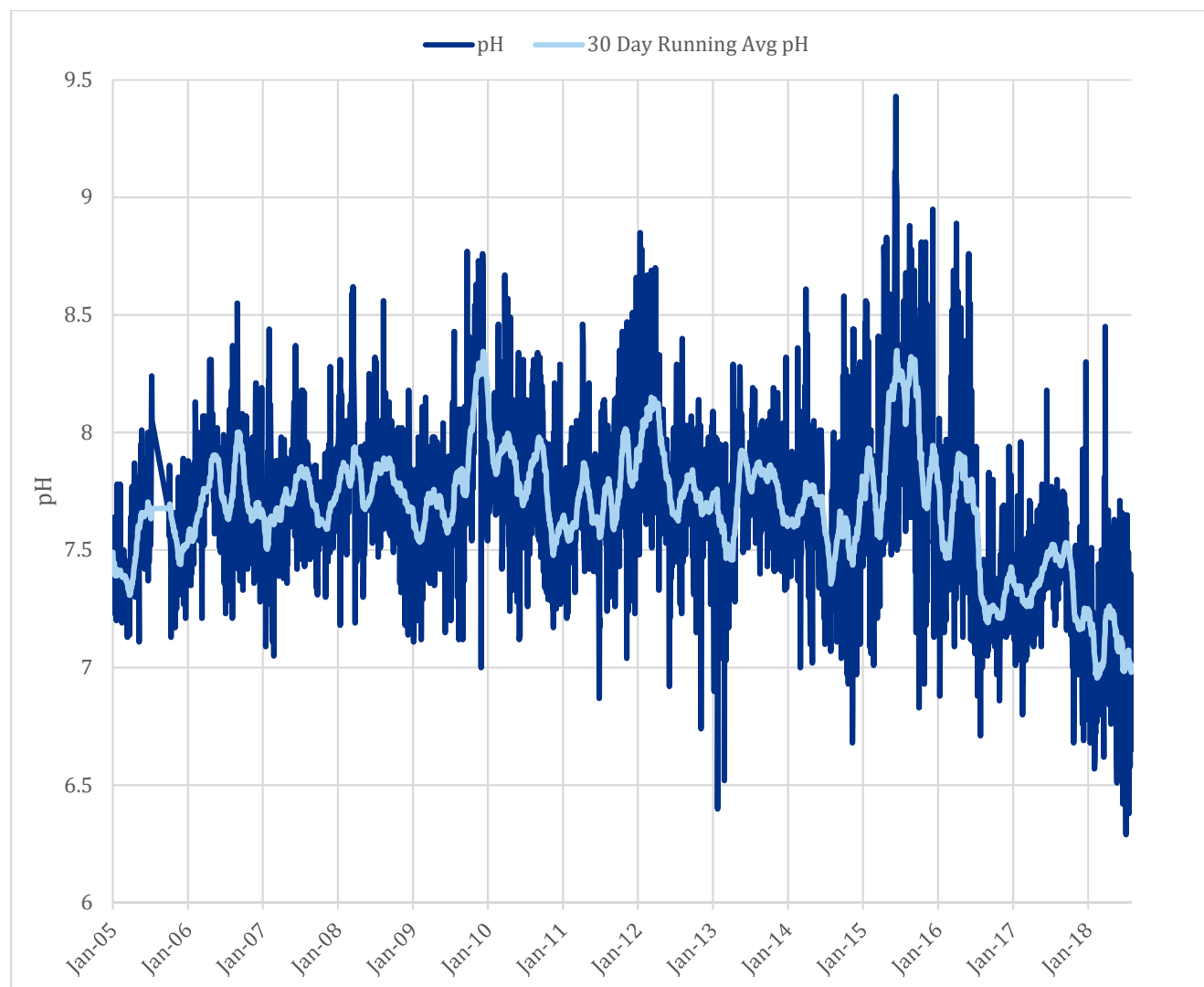


Figure 3-18 – Historic Valley Road Rechlorination Station pH (Distribution System POE) (2005 – 2018)

Regarding the daily fluctuations in pH experienced at the Pequannock WTP and the Valley Road Rechlorination Station, as shown in Figures 3-17 and 3-18, respectively, it is believed that the fluctuations are due primarily to the lime system operating challenges and not a result of buffering capacity. Newark has since made modifications to the system to increase the consistency of the lime dose at the Pequannock WTP. The alkalinity of the Pequannock water ranges between 10 and 35 mg/L as CaCO_3 with an average of approximately 22 mg/L as CaCO_3 and the DIC is approximately 8.5 mg/L as CaCO_3 . Based on water quality in other similar water systems, alkalinity and DIC levels in this range should be sufficient to maintain a consistent pH.

As mentioned, the fluctuations in pH experienced at the plant and across the system over the last few years are likely a result of operational challenges with the lime system at the Pequannock WTP, which have been recently addressed. This is evident from the historic daily fluctuations experienced in pH at the Pequannock WTP POE, while the pH across the distribution system on a given day is fairly consistent. This can be seen from comparing the pH values from the

Pequannock Gradient's WQPs on a given date. As shown in **Figure 3-19**, the pH range is fairly consistent across the large distribution system area.

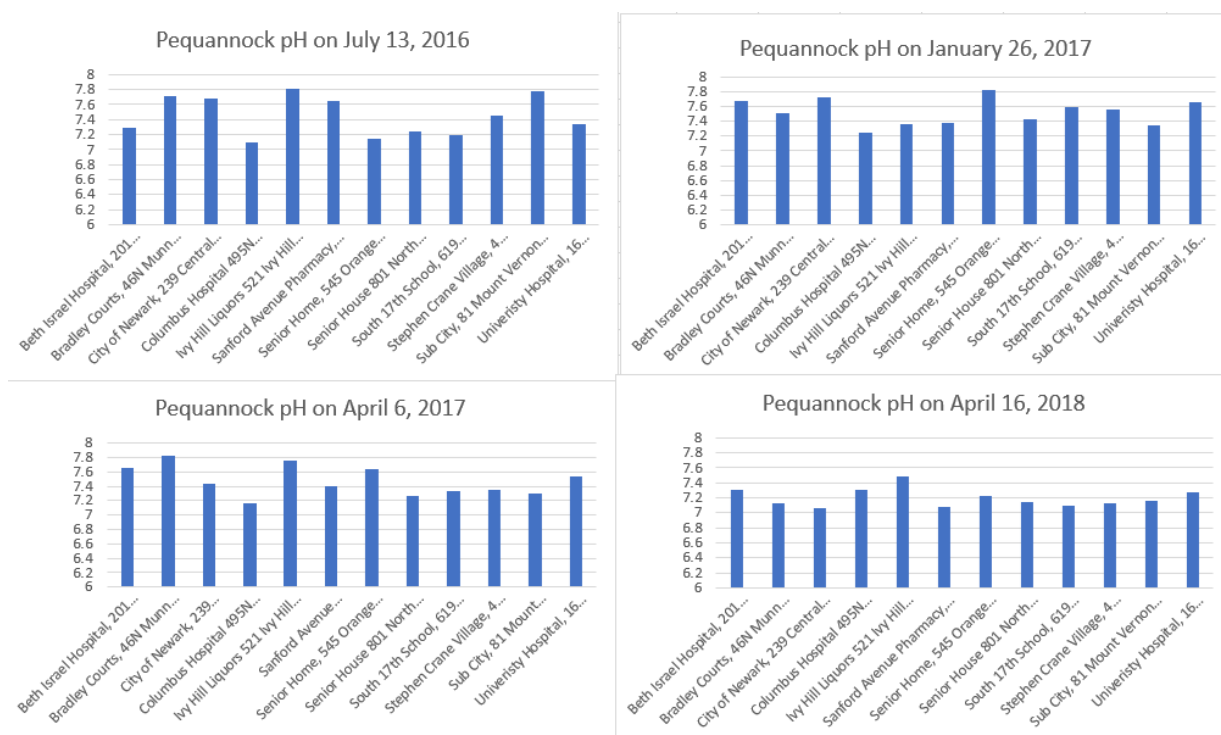


Figure 3-19 – Pequannock Gradient pH Values Across the Distribution System

3.3.2 Historic Chlorine Residual – Valley Road Rechlorination Station

Historic free chlorine residuals at the Valley Road Rechlorination Station, which is the point-of-entry into the distribution system for all but a small amount of water that is supplied upstream directly to the Township of Pequannock, were analyzed to determine changes over time. Daily “post-rechlorination” data were provided by Newark for the period between 2005 and 2018. The data, shown in **Figure 3-20**, indicate that chlorine residual leaving the rechlorination station generally ranged between 0.8 and 1.1 mg/L until about mid-2009, when chlorine residual trended steadily upwards to a range of 1.0 to 1.2 mg/L to mid-2015, and then continued to increase to a range of 1.1 to 1.3 mg/L until mid-2018. Current chlorine residual appears to be trending downward towards an average of 1.0 mg/L in the last few months. In general, the chlorine residuals have been held fairly constant on a 30-day running average over the dataset at the Valley Road Rechlorination Station, although there are some significant daily variations.

Additional chlorine residual data at the Valley Road Rechlorination Station was provided by Newark for years prior to the silicate addition. In 1984, chlorine residuals generally ranged between 1.0 and 1.2 mg/L. In 1989-1990, chlorine residual was reported to be consistently 1.0 mg/L.

Section 3 • Historic Water Quality and Chemical Usage Data

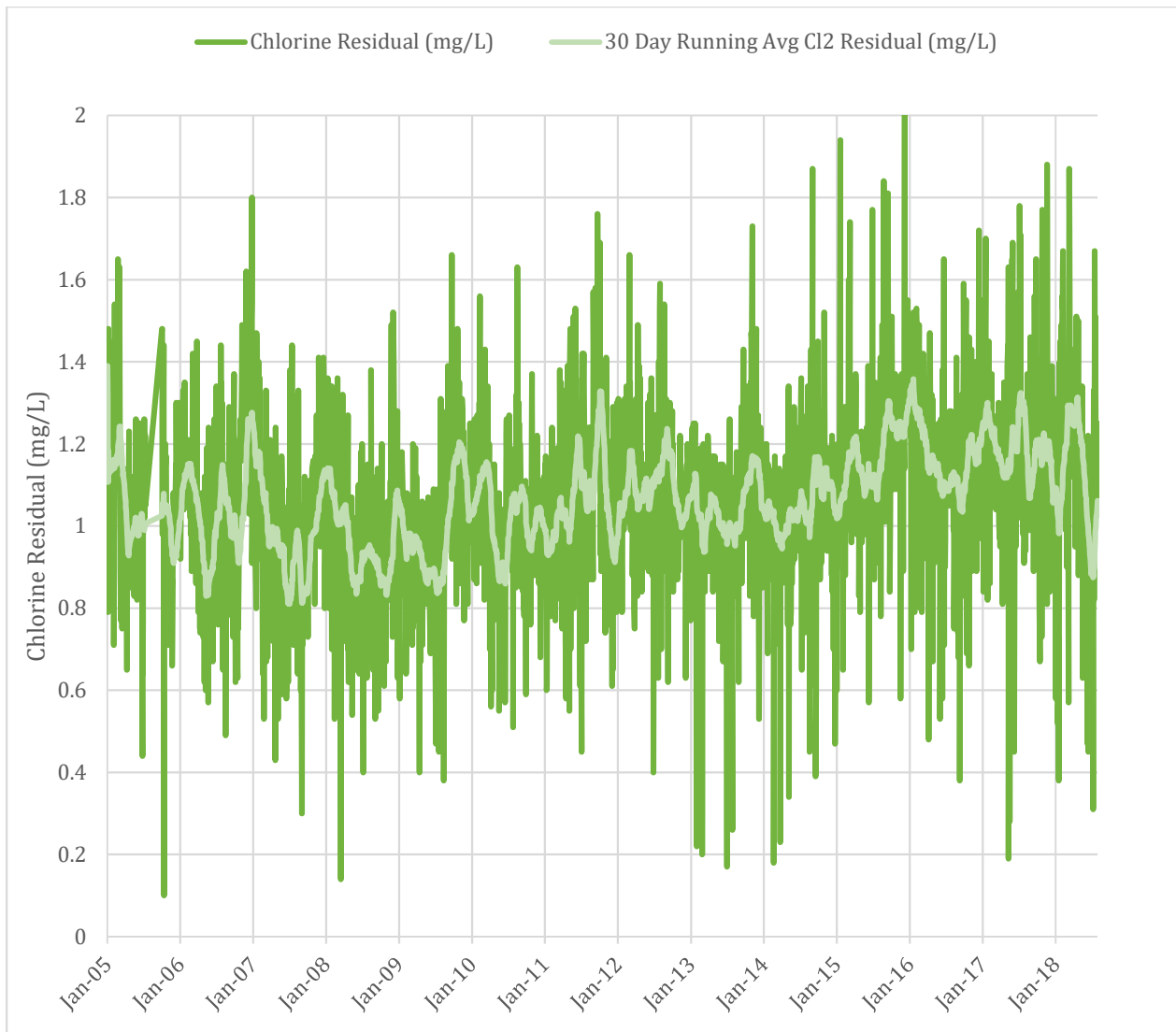


Figure 3-20 – Historic Valley Road Rechlorination Station Post Chlorine Residual (Distribution System POE) (2005 – 2018)

Section 4

Lead Sequential Sampling

The City of Newark conducted sequential sampling at two locations in September 2018. The purpose of this effort was to pinpoint potential sources of lead that exist within the service line and premise plumbing from the service connection in the street to the drinking water tap in the house. Sequential sampling is an additional tool to assist in developing an understanding of the system as part of the CCT optimization. The sources of lead at the tap measured in sequential samples include lead service lines, lead-based materials contained in the premise piping (e.g., leaded solder, brass/bronze fittings, galvanized piping), faucets, and water meters.

4.1 Sequential Sampling Program Protocol

The sequential sampling program consisted of collecting the full volume of water between the kitchen faucet and the water main in small increments allowing for the isolation of water from various plumbing components, such as, but not limited to, fixtures, valves, pipe materials and meters. A memorandum dated September 10, 2018 by CDM Smith titled “Sequential Sampling Program Protocol for Tracking Lead in Drinking Water” provided the protocol for performing the sequential sampling.

In general, the sequential sampling process consists of the following:

1. **Site Audit** - An initial visit to each home was conducted to document the cold-water piping, beginning at the faucet and traced back towards the water main in the street. This was used to calculate the volume in the water service line and determine the number and timing of samples needed for collection.
2. **Sample Collection and Analysis** - Sequential sampling is conducted after a stagnation period, between 6 to 12 hours, per the Lead and Copper Rule requirements. A 10-minute flush is conducted, without removing the aerators, prior to the stagnation period. Samples are taken at the kitchen sink in increments of 500 mL, or as determined by the site audit. A flushed sample is also taken at the end of the sequential program to test the water in the main. The aerator was not removed for the flushing or the sampling. Samples are analyzed for the following information:
 - *pH (first sample, a middle sample, and flushed final sample measured in the field)*
 - *Temperature (first sample, a middle sample, and flushed final sample measured in the field)*
 - *Free chlorine (first sample, a middle sample, and flushed final sample measured in the field)*
 - *Total Lead*
 - *Dissolved Lead*

- *Total Copper*
 - *Silica Residual (SiO₂) (first sample, a middle sample, and flushed final sample)*
 - *Alkalinity (first sample, a middle sample, and flushed final sample)*
 - *Conductivity (first sample, a middle sample, and flushed final sample)*
3. **Data Evaluation** – Once the samples are analyzed, the profile is plotted with cumulative volume on the X-axis and lead results on the Y-axis. Specific plumbing components are located along the service volume axis and the plumbing components most contributing to high lead values are noted.
 4. **Monitoring** – When the CCT is modified, the sequential sampling program is performed on a regular basis to ascertain the effectiveness of the new/modified CCT treatment.

4.2 Results of Newark's Initial Sequential Sampling

During the week of September 10, 2018, two residential locations were sampled for Newark's sequential sampling study as the initial baseline sampling, prior to any modifications to the CCT.

- Site A – South Ward
- Site B – North Ward

Each home has a lead service line and lead solder with copper indoor plumbing before the meter. Site A had cross-linked polyethylene (PEX) for the majority of their interior plumbing, with some sections of copper joined by lead solder. The locations of the sequential sampling sites are shown on **Figure 4-1**, including proximity to the harvested lead service lines that were sent to the EPA for pipe scale analysis discussed in Section 5.

Samples for total lead, dissolved lead and copper were taken every 500 mL as described in Section 4.1. It was estimated that Site A needed 15 samples and Site B needed 12 samples to encompass the entire interior plumbing and service line prior to reaching the main. After the final sample on the service line, the faucet was flushed for 10 minutes and another sample was taken at each house.

Background water quality collected at the time of the testing for each home is provided in **Table 4-1**. The background water quality was analyzed at the start of the testing (first draw sample), the middle of the testing (middle sample) and after a 10-minute flush (flushed sample). As can be seen in **Table 4-1**, the free chlorine residual is significantly less at Site A in South Ward than at Site B in the North Ward. This is to be expected as the North Ward is closer to the Valley Road Rechlorination Station and the South Ward is located at the other end of the distribution system.

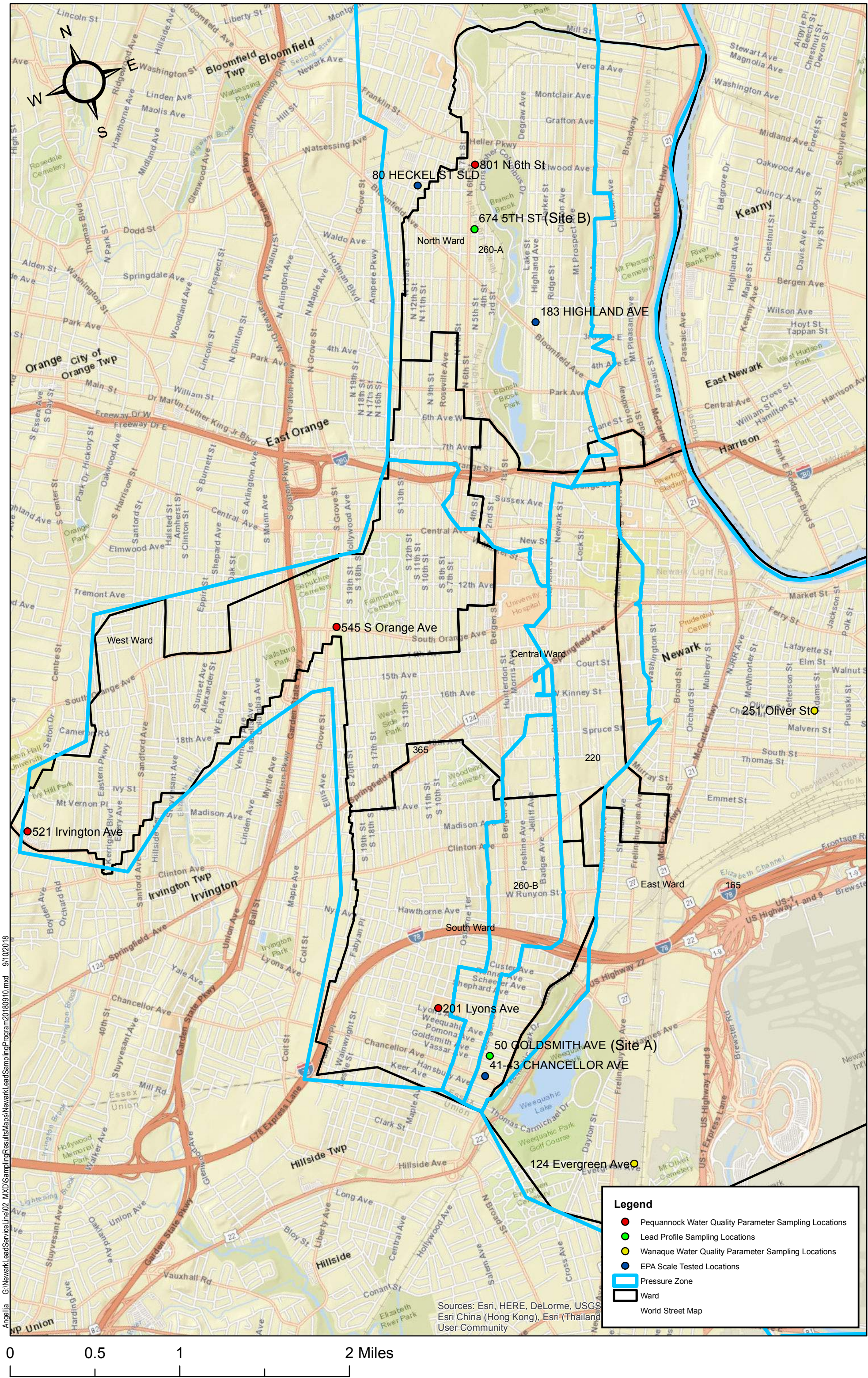


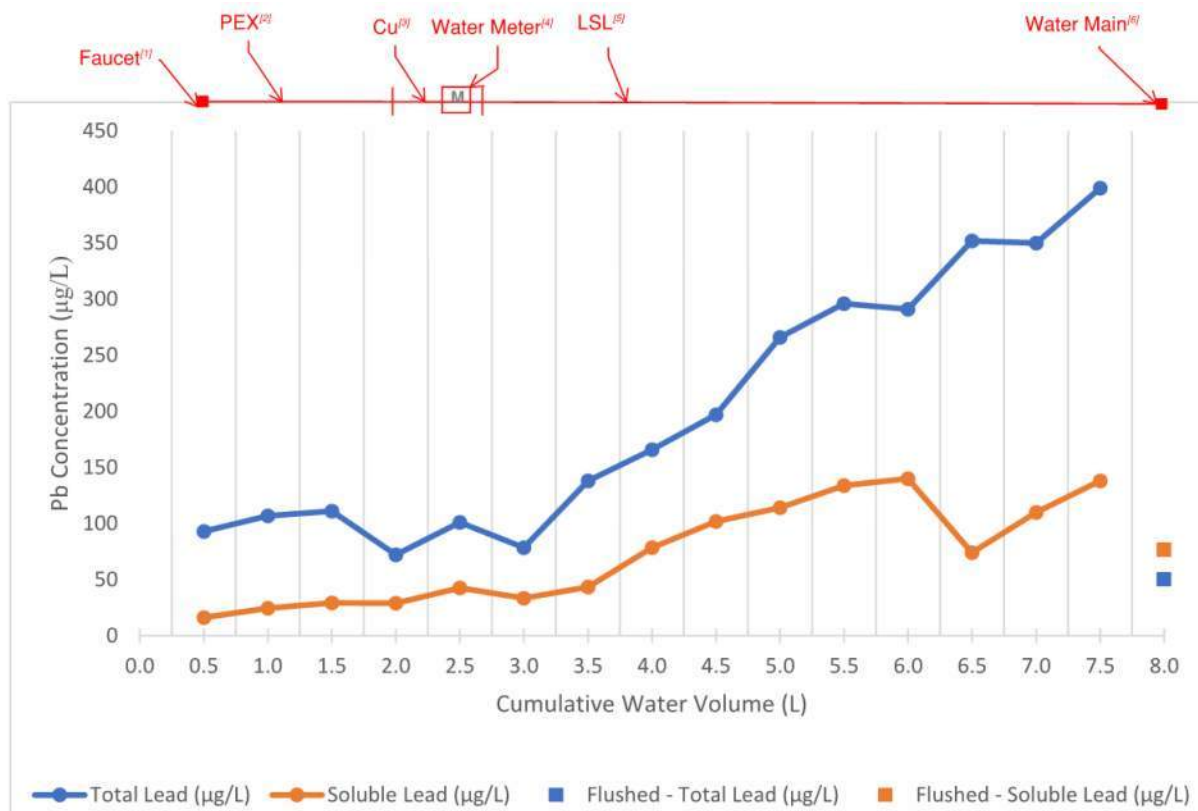
Table 4-1 – Water Quality Analysis at Sequential Sampling Sites

	Site A – South Ward			Site B – North Ward		
	First Draw Sample	Middle Sample	Flushed Sample	First Draw Sample	Middle Sample	Flushed Sample
pH	7.91	7.13	7.66	7.62	7.37	7.32
Temp (deg C)	20.9	20.7	21.6	21	22	22
Free Cl₂ (mg/L)	0.02	0.04	0.21	0.22	1.21	1.04
Alkalinity (mg/L CaCO₃)	34	34	36	34	35	33
Conductivity (uMhos/cm)	210	238	206	221	214	222
Silica (mg/L SiO₂)	7.48	7.38	8.17	8.10	8.33	8.70

Total lead and soluble lead were plotted against the cumulative water volume in a profile to identify lead contributions from different plumbing materials. The difference between the total lead and soluble lead is insoluble or particulate lead. Particulate lead is typically a result of scouring of deposits off the pipe wall or disturbing the scale layers that have formed over time, causing them to slough off the pipes. Soluble lead is dissolved lead that has leached from the piping into the water. The profile for Site A is shown in **Figure 4-2** and the profile for Site B is shown in **Figure 4-3**. Plumbing fixtures and materials are shown above each profile for correlation of plumbing fixtures to the samples. The estimated total lead, soluble lead and particulate lead results in the samples at Site A and Site B corresponding with the figures are listed in **Table 4-2** and **Table 4-3**, respectively.

The following are the observations for the lead profile results for Site A – South Ward, as shown in **Figure 4-2** and listed in **Table 4-2**:

- The highest lead levels at this address were found in the lead service line (LSL) pipe section. Soluble lead peaked at 140 µg/L and total lead peaked at 399 µg/L.
- Significant particulate lead was found at this address. The particulate lead may be a sign of the breakdown of a protective scale on the LSL which is further discussed in Section 5. It may also indicate that some particulate lead collected on the aerator after the flushing (or prior to that) and was present throughout the sampling.
- Both soluble and insoluble lead levels are high, indicating the current CCT is not optimized.
- Silica concentrations were an average of 7.68 mg/L as SiO₂, which generally coincides with the Pequannock WTP delivered water concentrations measured at the Test House.



^[1] Kitchen Faucet Location, ^[2] Cross-Linked Polyethylene Pipe Segment, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

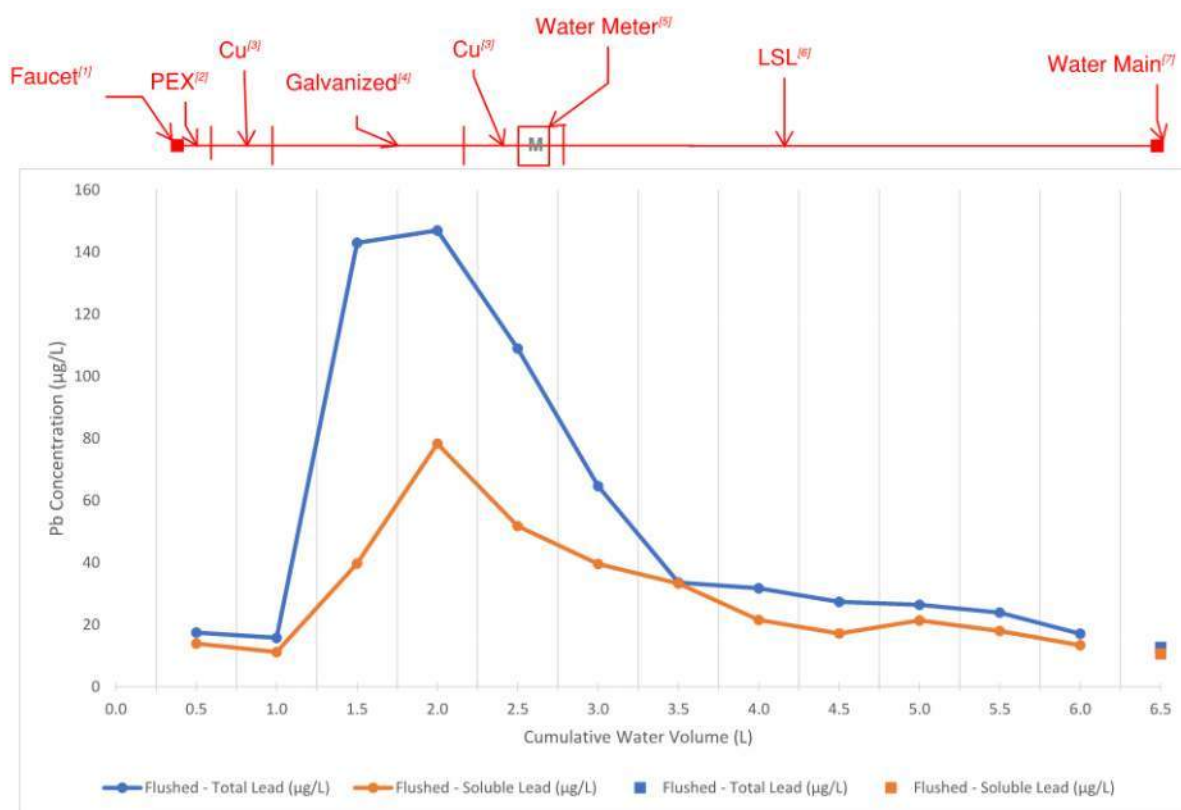
Figure 4-2 – Site A – South Ward Lead Profile – September 10, 2018

Table 4-2 – Site A – South Ward Lead Results

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)	Particulate Lead (µg/L)
A1	93.1	16.2	76.9
A2	107	24.6	82.4
A3	111	29.4	81.6
A4	72.2	29.1	43.1
A5	101	42.5	58.5
A6	78.6	33.4	45.2
A7	138	43.4	94.6
A8	166	78.4	87.6
A9	197	102	95
A10	266	114	152
A11	296	134	162
A12	291	140	151
A13	352	74	278
A14	350	110	240
A15	399	138	261
Flushed	50.5	76.6	0

The following are the observations for the lead profile results for Site B – North Ward, as shown in **Figure 4-3** and listed in **Table 4-3**:

- The highest lead levels at this address were found in the galvanized steel pipe section that is likely lead-lined, and the copper pipe section with lead-soldered joints. Soluble lead peaked at 78.3 µg/L and total lead peaked at 147 µg/L.
- Particulate lead was evident in the pipeline for 3 samples – liters 2.0, 2.5 and 3.0. The high particulate lead levels may be a sign of breakdown of a protective scale, which is further discussed in Section 5.
- Both soluble and insoluble lead levels are high, indicating the current CCT is not optimized.
- Silica concentrations were an average of 8.38 mg/L as SiO₂, which generally coincides with the Pequannock WTP delivered water concentrations measured at the Test House. The silica concentrations found in the North Ward were slightly greater than the concentrations found in the South Ward site (Site A).



[1] Kitchen Faucet Location, [2] Cross-Linked Polyethylene Pipe Segment, [3] Copper Pipe Segment, [4] Galvanized Steel Pipe Segment, [5] Water Meter Location, [6] Lead Service Line Pipe Segment, [7] Water Main Location

Figure 4-3 – Site B – North Ward Lead Profile – September 11, 2018

Table 4-3 – Site B – North Ward Lead Results

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)	Particulate Lead (µg/L)
B1	17.5	13.9	3.6
B2	15.8	11.2	4.6
B3	143	39.7	103.3
B4	147	78.3	68.7
B5	109	51.8	57.2
B6	64.6	39.6	25
B7	33.6	33.3	0.3
B8	31.7	21.5	10.2
B9	27.4	17.2	10.2
B10	26.4	21.4	5
B11	23.9	18	5.9
B12	17.1	13.4	3.7
Flushed	12.8	10.5	2.3

4.3 Discussion

The sequential sampling performed at the two locations on opposite ends of Newark's distribution system indicates that the current CCT is not effective at controlling soluble lead release into Newark's drinking water. Despite dissolved silica concentrations of approximately 8 mg/L as SiO₂ and the existence of a silica crust on the pipe walls (see EPA scale analysis in Section 5), the soluble lead concentration is still well above the EPA's LCR Action Level for lead. In addition, if a passivating scale (a protective layer on the pipe wall formed through chemical reactions between the water and carrier pipe) was intact and functioning as a lead-containing mineral scale to limit lead solubility, the lead levels would be expected to be much lower (Boyd, et al., 2008) than what was found. This indicates that the scales on the pipes in these two homes are not functioning as protective corrosion control scales and may be breaking down under the current water quality conditions. Regarding particulate lead, both homes had appreciable particulate lead in their tap water at the time the sequential sampling was conducted. This could be a result of lead-containing sediment in the service line, particulates that collected in the aerator, active breakdown of lead mineral scales on the pipe walls, or most likely a combination of these factors. After the sampling was conducted, it was reported that the home in the South Ward (Site A) has performed some recent plumbing improvements by replacing sections of copper and galvanized pipe with new copper and new PEX plumbing. Both homeowners were contacted to take precautions against lead contamination and Newark replaced their lead service lines with copper lines.

Lead sequential sampling is a useful tool to isolate the source of lead in tap water in a given home, to evaluate the magnitude of the current lead exposure to the public, and to evaluate differences in lead levels that may exist throughout the distribution system. It is recommended that additional sequential sampling be performed in homes in other Wards in Newark's distribution system. It is also recommended that Site A be re-tested after cleaning out the aerator and flushing

without the aerator to see if the high particulate lead results were due to a build-up of particulate lead behind the aerator.

In addition to evaluating the current level of lead in the Newark system, lead sequential sampling can be used as a tool to monitor the effectiveness of CCT implementation. It is recommended that a few homes be sampled monthly during any modifications to the system's CCT until lead levels stabilize.

Section 5

Pipe Scale Analysis

In February and March 2018, Newark sent three lead service pipes from the City's distribution system to the EPA Advanced Materials and Solids Analysis Research Core in Cincinnati, OH for characterization of the solid phases on the pipe walls. The pipes came from the following addresses:

- 43 Chancellor Avenue (South Ward)
- 80 Heckel Street (North Ward)
- 183 Highland Avenue (North Ward)

In October 2018, Newark sent the lead service pipes from the locations where sequential sampling was conducted in September 2018, to the EPA Advanced Materials and Solids Analysis Research Core in Cincinnati, OH for analyzing. The pipes came from the following locations, see Section 4 for reference:

- Site A – 50 Goldsmith Avenue (South Ward)
- Site B – 674 N 5th Street (North Ward)

The locations listed above are shown on the map in **Figure 4-1**. This section presents the results of the analyses that EPA performed on the pipe scales.

Analysis of scales from pipes that reflect actual distribution system conditions provides a direct indication of the effectiveness of a current treatment process to control lead release. Knowledge of the characteristics and behavior of the lead solids that have been formed on the pipe walls can be integrated with water quality and operational information to understand mechanisms of corrosion inhibition, speciation of metals, and predictions of lead mobility/stability, and can assist in implementation of corrective treatment changes. Knowing how a contaminant is chemically associated in distribution system scale materials can help with estimating the probability of unintended adverse consequences of treatment or water quality changes.

5.1 EPA Scale Analysis Testing and Results

The EPA conducted the following tests on the three lead pipes:

- X-ray diffraction (XRD) analysis – identifies crystalline mineral compounds
- Scanning electron microscopy (SEM)/Energy dispersive spectroscopy (EDS) elemental mapping – identifies general areas where different elements exist within the scale

The testing evaluated the scales in different layers on the pipe walls, which can indicate the history of water chemistry impacts over time. The technique involves separating each solid phase

Section 5 • Pipe Scale Analysis

layer for analysis, from the outermost layer (the layer in direct contact with the flowing water) to the innermost layer (the layer directly against the lead pipe wall).

The EPA results for 43 Chancellor Avenue, 80 Heckel Street and 183 Highland Avenue were provided on September 21, 2018. The EPA results for 50 Goldsmith Avenue and 674 5th Street were provided on December 14, 2018. **Figures 5-1 through 5-5** show images of the pipe scales in cross section for the each of the five sites. The entire EPA report is included as **Appendix A**. A summary of the compounds found at each location from the outermost layer in contact with the flowing water (L1) to the innermost layer adjacent to the pipe wall (highest “L”) is provided in **Table 5-1**. The “+” indicates the relative presence of a compound in the scale analyzed.



Figure 5-1 – Lead Scale Images for Pipe Extracted from 43 Chancellor Avenue



Figure 5-2 – Lead Scale Images for Pipe Extracted from 80 Heckel Street



Figure 5-3 – Lead Scale Images for Pipe Extracted from 183 Highland Avenue

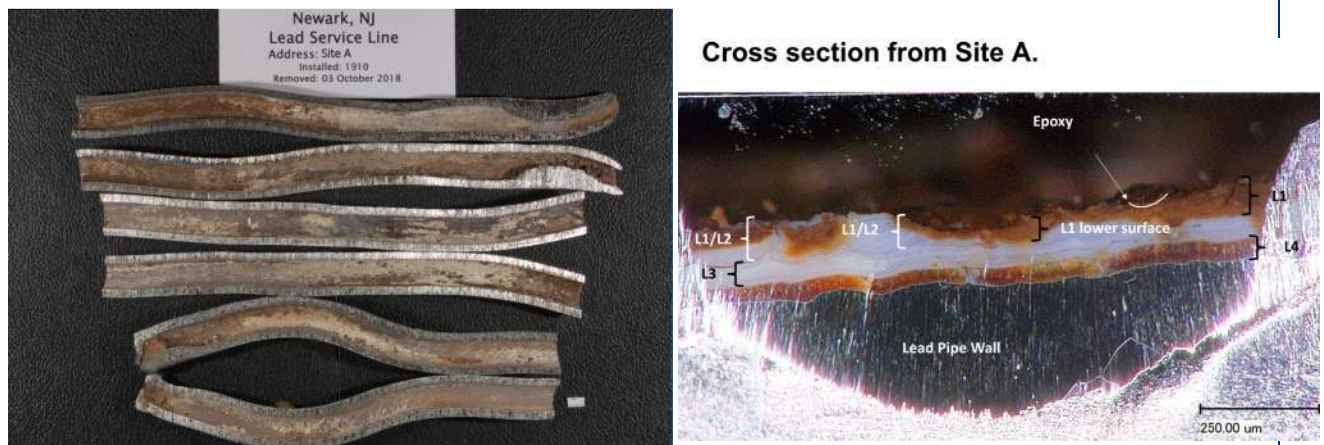


Figure 5-4 – Lead Scale Images for Pipe Extracted from 50 Goldsmith Avenue

Figure 5-5 – Lead Scale Images for Pipe Extracted from 674 5th Street

Table 5-1 – General Characterization of Solid Phases in Pipe Deposits

Location	Layer	Hydrocerussite $Pb_3(CO_3)_2(OH)_2$	Cerussite $Pb(CO_3)$	Plattnerite PbO_2	Litharge PbO	Massicot PbO	Scrutinyite PbO_2
43 Chancellor Avenue (South Ward)	L1	++	+++	+	none	none	none
	L2	+++	++	+	none	none	none
	L3	+++	++	++	none	none	none
	L4	+++	+	++	+	none	none
	L5	++	+	none	+++	+	none
80 Heckel Street (North Ward)	L1	+++	+	+++	none	none	+
	L2	++	+	+++	none	none	+
	L3	++	none	+	+++	none	+
183 Highland Avenue (North Ward)	L1	+	none	+++	none	+	none
	L2	+++	none	+++	none	+	none
	L3	+	none	+	+++	+	none
50 Goldsmith (South Ward)	L1	+++	+	+	none	none	none
	L1/L2	+++	+	++	none	none	none
	L3	+++	+	+	none	none	none
	L4	++	+++	none	+++	none	none
674 5th Street (North Ward)	L1	+++	++	+++	none	none	none
	L2	+++	++	+++	none	none	none
	L3	+++	+	+++	none	none	none
	L4	+++	+	++	none	none	none
	L5	No Data	No Data	No Data	+++ ^[1]	No Data	No Data

Note: +++ = predominant, ++ = moderate, and + = trace/minor

^[1] L5 was not sampled due to breaking and was noted to most likely be Litharge (PbO) based on color and texture

The scales found on the outermost layers were primarily hydrocerussite, along with cerussite and plattnerite. Hydrocerussite and cerussite are divalent Pb(II) compounds that are carbonate-based scales. In carbonate-based scales, the hydroxide (OH^-), carbonate (CO_3^{2-}), or bicarbonate (HCO_3^-) ions complex with the metal (i.e., lead) to form insoluble metal/hydroxide/carbonate compounds on the pipe walls. These different lead minerals have varying degrees of solubility. Cerussite is the most stable Pb(II) phase at pH 8–8.5. Cerussite is more soluble than hydrocerussite, which is the most stable Pb(II) phase at higher pH (≥ 9.0). It is unusual to find hydrocerussite as the dominant mineral phase at Newark's current operating range around pH 7.4.

Plattnerite (PbO_2) is a tetravalent Pb(IV) compound that is formed over time in waters with high redox potential (ORP). It is reported in the literature that a high ORP can be achieved with free chlorine at levels typically over 1.5 mg/L, and that the rate of formation of PbO_2 appears to increase with increasing pH (Boyd, et al., 2008). Pb(IV) has been observed in systems with free chlorine residuals less than 1.5 mg/L, including Newark. ORP data is not available from within the Newark distribution system so correlations with chlorine residual are not possible. Under these

conditions, PbO_2 typically dominates or coexists with Pb(II) mineral forms including hydrocerussite and cerussite. Plattnerite is less soluble than hydrocerussite and cerussite, making plattnerite more effective at achieving low lead levels when the proper (high ORP) water chemistry is maintained.

The pipe scales did not contain evidence of any crystalline Si-Pb compounds, indicating that silicate complexation with lead is not taking place to control soluble lead levels. However, a silica crust (SiO_2) was found on all pipes. The silica crust was found to be relatively porous and therefore not acting as an effective barrier against the outward flux of lead released from the pipe as the passivating lead layers (mainly plattnerite and hydrocerussite) were found behind the silica crust.

5.2 EPA Elemental Analysis Testing and Results

An elemental analysis was also performed via X-ray fluorescence (XRF) on the same five lead services lines discussed in **Section 5.1**. The XRF technology is able to assess the inorganic elemental composition of solid layers on the lead service lines through the solids extraction process. The EPA XRF results (Appendix A), provide the concentration of inorganic elements, expressed as micrograms per gram of solid (parts per million) or weight percent (AWWA, 2017).

It should be noted that at the time the results were provided by the EPA, the XRF was not calibrated for carbon; should carbon concentrations have been added, the accuracy of the Pb results would improve. However, the results are considered of sufficient accuracy to provide meaningful information.

To put the results below into context, the percentage (by weight) of lead (Pb) in the predominant scale complexes found on the pipes is 77.5% Pb in cerussite ($\text{Pb(CO}_3\text{)}$), 80.1% Pb in hydrocerussite ($\text{Pb}_3(\text{CO}_3)_2(\text{OH}_2)$), 86.6% Pb in Plattnerite (PbO_2), and 92.8% Pb in Litharge (PbO).

Table 5-2 provides a summary of the elemental data for the most common components found in each layer for the five locations. The sites are discussed individually below. The terminology “inner” refers to the scale layer directly against the lead pipe wall whereas “outer” refers to the scale layer in direct contact with the flowing water. The outermost layer is labeled as L1 and increases numerically, until reaching the innermost layer.

Table 5-2 – Summary of Scale Composition Elemental Analysis Results

Location	Layer	Elemental* % by Weight						
		Pb	Si	Fe	Al	Mn	Na	K
43 Chancellor Avenue (South Ward)	L1	69.44	2.90	4.77	1.49	< 0.5	No data	No data
	L2	92.14	< 0.50	< 0.50	< 0.50	< 0.50		
	L3	No data						
	L4	95.1	< 0.50	< 0.50	< 0.50	No data		
	L5	99.33	< 0.50	< 0.50	< 0.50			
80 Heckel Street (North Ward)	L1	75.37	2.63	1.23	1.61	1.8	No data	No data
	L2	96.39	0.61	< 0.50	< 0.50	< 0.50		
	L3	98.23	< 0.50	< 0.50	< 0.50	No data		

Location	Layer	Elemental* % by Weight						
		Pb	Si	Fe	Al	Mn	Na	K
183 Highland Avenue (North Ward)	L1	93.16	2.52	< 0.50	0.63	< 0.50	< 0.50	No data
	L2	40.57	30.15	0.94	2.42	< 0.50	0.91	0.72
	L3	97.74	1.42	< 0.50	< 0.50	No data	No data	No data
50 Goldsmith Ave (South Ward)	L1/L2	89.15	1.15	1.02	< 0.50	< 0.50	No data	No data
	L3	89.01	< 0.50	< 0.50	< 0.50	No data		
	L4	86.68	< 0.50	< 0.50	No data	No data		
674 5 th Street (North Ward)	L1	82.23	2.60	3.51	1.97	1.00	No data	No data
	L2	89.12	0.89	1.07	0.65	< 0.50		
	L3	91.08	< 0.50	0.54	< 0.50	< 0.50		
	L4	90.55	< 0.50	< 0.50	< 0.50	No data		
	L5	No data						

*Pb = lead; Si = silica; Fe = iron; Al = aluminum; Mn = manganese; Na = sodium; K = potassium

43 Chancellor Avenue

The outermost layer had the most amount of silica (Si), iron (Fe) and aluminum (Al) which substantially decreased in the subsequent layers. The outermost layer had the lowest amount of lead and lead increased significantly in the innermost layer. The general trend of increasing Pb from the outer to inner layers corresponds to the scale composition consisting of lead carbonates to a mix of lead carbonate with PbO₂, then to PbO-dominated in L5, as presented in **Table 5-1**. The increase in Pb in the layers moving from outer to inner is expected as the inner layers are closer to the source of lead (the pipe). Other elements were traced in the lead layers, but were less than 0.5% by weight, such as calcium (Ca), copper (Cu), nickel (Ni), phosphorous (P), sulfur (S), antimony (Sb), and zinc (Zn).

80 Heckel Street

The results are similar to those at 43 Chancellor Avenue, where the outermost layer had the greatest amount of Si, Fe Al and Mn, which substantially decreased in the inner layers (L1 to L3); however, the outermost layer had a higher percentage of Pb than 43 Chancellor, which also significantly increased in L3. The general trend of increasing Pb from the outer to inner layers corresponds to the scale composition consisting of a mix of lead carbonate and PbO₂ in L1, to less lead carbonate in L2, and then PbO-dominated in L3. Other elements were traced in the lead layers, but were less than 0.5% by weight, such as bismuth (Bi), Ca, Cu, Ni, P, S, and Zn.

183 Highland Avenue

The results at this location were different than the other two lead service line locations. The percentage of Pb was high in L1, dropped quite sharply in L2, and increased again in L3. This same pattern is demonstrated for Si, and to a lesser extent for Fe and Al. Traces of sodium (Na) increased in L2 and traces of potassium (K) were only found in L2. It cannot be determined how much of the Si in L2 originated from the quartz grains (trench sediment contamination) on the surface of the scale as opposed to being a result of CCT. However, it is speculated that the high percentage of Si and low percentage of Pb in L2 was noted to be likely due to the large amount of quartz sediment incorporated into the sample that was sent for analysis. Other elements were

traced in the lead layers, but were less than 0.5% by weight, such as Bi, Ca, Cu, Mg, Ni, P, S, titanium (Ti) and Zn.

50 Goldsmith Avenue

The scale analysis results for 50 Goldsmith Avenue were different from 43 Chancellor Avenue, which is also located in the South Ward and nearby. This is due to having layers of scale (L1-L4) already sloughed off in multiple areas while the lead service line was in service, as seen in **Figure 5-4**. However, both south ward locations had a predominant amount of litharge (PbO) in the innermost layer. The scale analysis and conditioning of the lead pipe agree with the sequential sampling results. As demonstrated in **Figure 4-2**, the lead continuously increased and lowered after flushing for 10 minutes. There are sections where the lead pipe would have been in direct contact with the water, due to segments of layered scaling sloughing off.

The percentage of Pb remained high across all layers, with a very slight decrease from the outer to the innermost layers. It was noted that there was insufficient sample for analysis of L1 by itself and L1/L2 were combined for analysis. The elements Si and Fe had percent by weight values of 1.15 and 1.02, respectfully, in L1/L2 that decreased to trace amounts reaching the innermost layer of the pipe. It was noted that some portion of the Si concentration observed in L1/L2 was contributed by sand (quartz) grains that contaminated the scale and originated from the trench sediment. Other elements were traced in the lead layers, but were less than 0.5% by weight, such as Al, Ca, Cr, Cu, Mn, Ni, P, and S. Although present in low amounts (less than 0.5% by weight), P concentrations observed at 50 Goldsmith Avenue were similar to concentrations observed at 43 Chancellor, which is located just a few streets away.

674 5th Street

The scale analysis results at this location are different than the other two North Ward service line locations. The outermost layer was predominantly hydrocerussite and plattnerite with a moderate amount of cerussite. L2 and L3 remain the same as L1, with regards to the lead compound. L3 also consisted of a complex laterally-heterogeneous mix of plattnerite and (hydroxy)carbonates (i.e., cerussite and hydrocerussite). Even though the innermost layer L5 was not tested sample due to it breaking into fragments, it was noted that it was composed mainly of litharge (PbO), based on color and texture, which is similar to both the other north ward scale analysis results.

The scale composition elemental analysis for 674 5th Street followed similar patterns to 80 Heckel St, which is also located in the North Ward. The percentage of Pb by weight followed an increase from the outermost to innermost layer. The outermost layer also had the highest amount of Si, Fe, Al and Mn, which decreased from the outer to inner layers. 674 5th Street had a higher elemental percentage by weight for Pb and Fe than 80 Heckel), but the Si and Al were within a 0.5% range. Additionally, 80 Heckel Street had a slightly higher elemental percentage by weight of Mn than 674 5th Street in the outermost layer. Other elements were traced in the lead layers, but were less than 0.5% by weight, such as Ca, chlorine (Cl), Cu, neodymium (Nd), Ni, P, S, Zn. Although very low, the P at 674 5th Street was similar to that at 43 Chancellor. The 5th street pipe is located in the North Ward with 80 Heckel and 183 Highland as its nearest neighbors, both of which have maximum XRF results for P as 0.03 % by weight.

5.3 Analysis of Results

5.3.1 Comparison of Sequential Sampling Results and Scale Analysis

More dominant plattnerite scales were found on the pipes harvested in the North Ward at 80 Heckel Street, 183 Highland Street and 674 5th Street where the chlorine residuals have likely always been the highest in the system because they are closest to the Rechlorination Station. This was confirmed by the lead sequential sampling results presented in Section 4. The North Ward address (674 5th Street) had a chlorine residual over 1.0 mg/L while the South Ward site (50 Goldsmith Avenue) had a chlorine residual of 0.21 mg/L in the water main and 0.04 mg/L in the service line. **Table 5-3** correlates the information from the EPA pipe scale analysis with the lead sequential sampling study based on proximity to each other. The test locations relative to each other geographically are provided in **Figure 4-1**. The solid phase (scale) minerals in the last column of **Table 5-3** are listed from most prominent to least prominent.

Table 5-3 – Comparison of Lead Sequential Sampling Data and EPA Scale Analysis Results

General Location	Chlorine Residual (mg/L)		pH		Most Prominent Scale Compounds Found
	First Draw	Flushed Sample	First Draw	Flushed Sample	
North Ward	0.22	1.04	7.62	7.32	Plattnerite > hydrocerussite > litharge
South Ward	0.02	0.21	7.91	7.66	Hydrocerussite > cerussite > plattnerite

As shown in **Tables 5-1** and **5-3**, the pipes from the South Ward (43 Chancellor Avenue and 50 Goldsmith Avenue) tested by EPA showed predominantly hydrocerussite, and cerussite scales, which are more soluble than plattnerite scales. This was also evident in the lead sequential sampling results presented in Section 4 where the soluble lead levels were higher at the South Ward profile (50 Goldsmith Avenue) than the North Ward profile (674 5th Street). This indicates that the current pipe scale in the South Ward is less effective at controlling soluble lead than the North Ward scale. The high particulate lead content also indicated that the scale could be sloughing off due to its porosity and physical instability. This was confirmed with the scale analysis results.

5.3.2 Formation of Tetravalent Lead (Pb(IV)) Scales

As noted above, free chlorine residual is an indicator of the ORP of the water. In highly oxidizing waters with high ORP, tetravalent lead (Pb(IV)) compounds, such as PbO₂, can form a scale on the pipes (Boyd, et al., 2008). The reaction time and concentration of chlorine residual needed to form tetravalent lead scales is unique to each system and is influenced by natural organic matter (NOM) and alkalinity (Boyd, et al., 2008), in addition to pH. Tetravalent lead scales are very effective at reducing lead corrosion in the system when the appropriate water chemistry is maintained. However, when the water chemistry is modified, such as if the ORP is lowered (e.g., due to a low free chlorine residual) and/or pH is lowered, the scales will destabilize relatively

quickly and result in release of particulate lead. Without the presence of a high ORP or the addition of orthophosphate to form highly insoluble lead-phosphate mineral phases, carbonate scales such as hydrocerussite and cerussite are the dominant mineral phases that will form and these mineral phases are more soluble, particularly at the lower pH values existing in the Newark distribution system. This appears to be the situation in both the North and South Wards according to the scales analyzed by the EPA and the results of the sequential sampling. The situation appears to be occurring to a greater degree in the South Ward.

When redox conditions change, the highly insoluble PbO_2 reduces back to the more soluble Pb(II) if the ORP is not maintained, thereby increasing soluble lead levels in the water. This can happen if the disinfectant changes, such as from free chlorine to chloramines, or if there is a loss of chlorine residual (DeSantis, Conversion of Lead Corrosion Scale Under Changing Redox Conditions, 2017). Newark does not have historic ORP data. However, chlorine residual data at the Rechlorination Station are presented in Section 3.3.2. The data show a recent slight drop in chlorine residual from a range of 1.1 to 1.3 mg/L to an average of approximately 1.0 mg/L which is not a significant enough decrease in ORP to reduce PbO_2 scales back to the more soluble Pb(II) scales based on that one factor alone.

Plattnerite (PbO_2) scales can also change and reduce back to more soluble Pb(II) if there is a reduction in pH in the system. Historic pH values presented in Section 3.3.1 indicate that pH was reduced appreciably in 2016. Before that time, pH was maintained above 8.0. It is possible that the ORP was high enough at that pH to form and maintain PbO_2 scales in Newark's system. This is discussed in more detail in Section 6.

The two EPA scale analysis reports provided in Appendix A (EPA, 2018) noted that the Newark plattnerite scales have a more complex internal structure compared to plattnerite-dominated scales they have observed from distribution systems with a history of stable water quality. With Newark's variability in water quality over time, the plattnerite scale may currently be unstable, resulting in particulate lead release. The results of the lead sequential sampling in Section 4 indicating high particulate lead concentrations further strengthens this presumption.

5.3.3 Additional Scale Analyses

Additional scale analyses are recommended to be performed in other wards in Newark, including one lead pipe from the West Ward and one lead pipe from the Central Ward, which are supplied mainly by water from Pequannock. Scale analyses are to be analyzed from lead service lines supplied water from Wanaque, which contains orthophosphate, under a separate memorandum. This will provide a useful comparison with the Pequannock system.

Section 6

Potential Causes of Elevated Lead Levels

6.1 Overview

Every water system is unique, based on its water chemistry and treatment history. Although there is not complete certainty as to the cause of the recent increase in lead levels in Newark, there are many factors that potentially contributed to it. This section reviews these factors in an attempt to explain the increase in lead in Newark's distribution system in 2017 and 2018.

The following factors may have influenced the 2017-2018 elevated lead levels in Newark's distribution system and are described in more detail in Sections 6.2 and 6.3 of this report:

- Decrease in pH in the distribution system
- LCR compliance sampling

The following factors may have played a role, but are less likely to have contributed significantly to the 2017-2018 elevated lead levels:

- **ORP.** Changes in ORP in the distribution system are unlikely to have contributed to the recent increase in elevated lead levels based on the 2005 to 2018 chlorine residual levels at the Valley Road Rechlorination Station, which were fairly consistent on a monthly average basis.
- **Silicate.** Based on all available information for this project, it seems that sodium silicate is acting as a pH adjustment chemical and not as a corrosion inhibitor. Therefore, the reported reduction in sodium silicate dosing since the late 1990s impacts lead levels insofar as it correlates with reduced pH leaving the Pequannock WTP. Although a silica layer was found on the LSLs analyzed by the EPA, the lead results in the sequential sampling indicate that the silica layer is not effectively preventing soluble lead release. It is believed that sodium silicate is not currently providing a beneficial impact on lead levels in the distribution system beyond pH adjustment. The impact of pH from reducing the sodium silicate dose is addressed in Section 6.2.
- **CSMR.** A CSMR of approximately 3 (range 1.9 – 3.8) has been consistent in the Newark system for at least 24 years and is unlikely to be contributing significantly to the recent increase in elevated lead levels. There is not enough data to accurately determine the CSMR in 2015 and 2016. The CSMR was calculated to be 5.1 from data collected in October 2017, as was shown in **Table 3-2**. This was a greater level than observed for the 20+ previous years, and results from an unusually low sulfate value, which appears to be an outlier.

6.2 Decrease in pH in the Distribution System

As presented in Section 3.3.1, the pH at the Valley Road Rechlorination Station, just upstream of the distribution system, fluctuated significantly between 2005 and 2018. As shown in **Figure 3-**

18, the average pH range was 7.6 to 8.0 from 2005 to 2012, with a few sustained periods above 8.0. After 2012, the pH decreased to an average range of 7.5 to 7.7, and then briefly returned to an average of 8.0 in 2015 for a few months. Starting in 2016, the pH decreased to the current average of approximately 7.0. **Figure 3-17** shows the pH leaving the Pequannock WTP over an even longer history, where the pH decrease is apparent. The graph shows a pH range of 8.5 to 9.0 in the 1990s, decreasing to a range of 8.0 to 8.3 until 2013, and then to the recent average of approximately 7.1.

The reason for the decrease in pH is primarily due to Newark's efforts to reduce disinfection byproduct formation and improve primary disinfection at the Pequannock WTP. Previous operational difficulties with the quicklime system that was removed in 2017, the new hydrated lime system and the sodium silicate feed system discussed in Section 2, may have also temporarily contributed to the decrease in pH, however, it is believed that the main driver for the lower pH was to meet disinfection requirements.

The pH within the distribution system has a major impact on corrosion control. In systems without orthophosphate, control of lead relies on the formation of carbonate scales or tetravalent lead (Pb(IV)) scales. For carbonate scales, such as cerussite and hydrocerussite, pH and alkalinity are critical parameters in their formation. For tetravalent lead, scale formation is based on pH, ORP and the concentration of natural organic material. Both types of scales are found in Newark's distribution system. The following section describes the impact of reduced pH on these two types of lead scales.

6.2.1 pH Impacts on Pb(II) Scales

Section 7 discusses the solubility of lead carbonate mineral scales and provides an estimation of the required pH for carbonate scales alone to reduce lead levels substantially in Newark's distribution system. As presented in Section 7, the pH would need to be over 9.0 to theoretically reduce soluble lead in Newark's system using Pb(II) carbonate scales.

Based on corrosion chemistry and solubility modeling, a pH of 8.0 or less would not reduce soluble Pb(II) significantly enough to be in compliance with the LCR. Since Newark was in compliance with the LCR from 1998 to 2015, when the pH ranged from 7.6 to 8.0 during the majority of that period, it is possible that tetravalent lead (Pb(IV)) or plattnerite scales were more prominent during that time, providing some degree of protection against lead release.

6.2.2 pH Impacts on Pb(IV) Scales

Plattnerite is more likely to form in systems with higher pH values, high oxidative conditions (i.e., high ORP) and low organic matter conditions. Plattnerite is extremely insoluble and, if the scale is stable with consistent water quality, would be more protective against lead being released than Pb(II) scales (Boyd, et al., 2008).

ORP is a quantitative measure of the state of oxidation in water and varies with pH, temperature, and dissolved inorganic carbon (DIC), but is primarily driven by the type and concentration of disinfectant in the water (e.g., chlorine or chloramines). ORP is measured using a platinum reference electrode and reported in units of volts (V), and then normalized with respect to a standard hydrogen electrode and reported as electric potential (Eh).

Figure 6-1 illustrates an Eh-pH (Pourbaix) diagram for system conditions with a dissolved DIC level of 8.5 mg/L as C, in the range of what is seen in Newark's system. Eh-pH diagrams, also called predominance area diagrams, are based on theory, and the boundaries of the species can vary, depending upon the data used to construct the diagram. In **Figure 6-1**, Eh represents ORP, which correlates with chlorine residual. At a sufficiently high ORP, plattnerite (PbO_2) would form in this water across a wide range of pH conditions, with formation occurring more dominantly at higher pH levels. As shown on **Figure 6-1**, plattnerite is in the dominant phase when operating at historical pH values of 8.0 and above at high ORP values. By lowering pH to 7.0, predicted dominance shifts towards PbCO_3 and Pb^{2+} , this leading to PbO_2 instability. It should be noted that ORP data collection is not a regulatory requirement and historic values are not available for the Newark system.

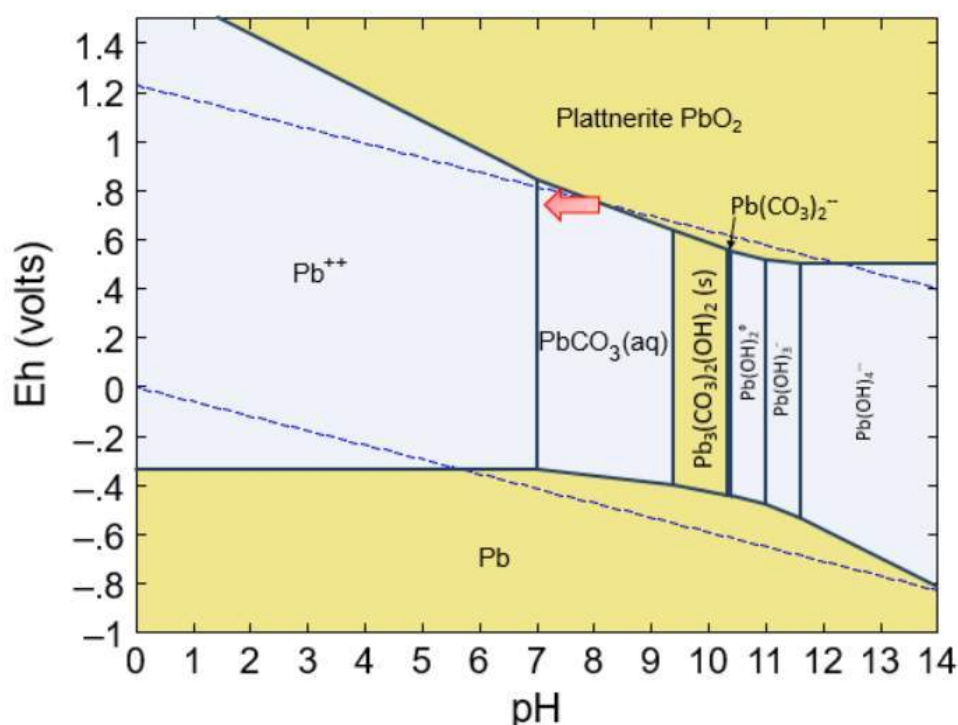


Figure 6-1 – Potential-pH (Pourbaix) Diagram for Water with DIC = 8.5 mg C/L

In systems where there has been a known increase in lead at the tap resulting from destabilization of Pb(IV) scales, it is typically a result of a decrease in ORP, such as changing the disinfectant from free chlorine to chloramines. As can be seen in **Figure 6-1**, decreasing ORP (Eh) would convert PbO_2 , an extremely insoluble compound, to the more soluble Pb(II) carbonate compounds, resulting in lead release into the water.

Additionally, if the ORP is stable but the pH decreases, then conditions amenable to PbO_2 dominance change and cause previously stable PbO_2 to become unstable and convert to more soluble Pb(II) carbonate compounds and soluble Pb (Pb^{++}). This is represented by the red arrow shown on **Figure 6-1**. If this situation occurs, one would expect to see elevated levels of soluble lead during sequential sampling, as well as insoluble (particulate) lead as a result of the scale becoming destabilized. As presented in Section 4, the results of the sequential sampling in

Newark showed elevated levels of both soluble and particulate lead, indicating that conversion from PbO_2 to Pb(II) scales and Pb^{++} may currently be taking place at the reduced pH of Newark's distribution system.

Because both Pb(II) scales and Pb(IV) scales were found on Newark's LSLs and reducing pH adversely affects the solubility of both types of scales, the reduction in pH in the Newark distribution system is likely the main cause for the 2017 and 2018 elevated lead levels. Raising the pH to levels that will provide the desirable chemistry for these scales to re-stabilize and control lead release will risk simultaneous compliance with primary disinfection and disinfection byproduct regulations. Simply returning to the corrosion control strategy Newark had in the 1990s and early 2000s to comply with LCR is no longer considered a viable option unless corrective actions are taken to achieve primary disinfection and disinfection byproduct compliance (e.g., alternate disinfectant, removal of disinfection byproduct precursors, etc.).

6.2.3 Sodium Silicate and pH

The primary corrosion protection offered by sodium silicate is the increase in pH that comes from the addition of the chemical, particularly in low alkalinity waters (AWWA, 2017). The 1994 Corrosion Study recommended a starting dose of 24 mg/L as SiO_2 (or 72 mg/L as sodium silicate) and a maintenance dose of 8 mg/L as SiO_2 (or 24 mg/L as sodium silicate), which resulted in a finished water pH between 8.4 and 9.0 (Newark, 1994). If the study recommendations were implemented in the mid-1990s, this would explain the pH levels of over 8.5 in the Pequannock WTP finished water as shown in **Figure 3-17**. The current silicate dosing of approximately 12 to 15 mg/L (or 3.5 to 4.4 mg/L as SiO_2) may partially explain the decrease in pH seen over time as shown in **Figure 3-17**.

As corrosion control chemistry transitions occur slowly over time, it cannot be determined exactly when the lead levels started to increase. However, trends of increased lead levels in the compliance samples, under the LCR, aid in determining the effectiveness of corrosion control. As mentioned in Section 6.2.2, it would not be advisable at this time for Newark to increase the sodium silicate dose to the levels recommended in the 1994 corrosion optimization study, thereby increasing pH (8.4-9.0), unless a strategy for compliance with disinfection and disinfection byproduct regulations is developed and unless the solution was long-term.

6.3 LCR Compliance Sampling

It is well-known that LCR compliance sampling does not always reflect actual lead levels that customers are exposed to and does not always confirm if CCT is optimized. In the case of Newark, the following LCR compliance sampling factors could have affected the early detection of an ongoing or growing lead problem:

- First-draw sample volume required by the LCR
- Error resulting from customer collection of samples
- Accuracy of inventory and confirmation of sample sites
- Proportional mix of Pequannock and Wanaque sampling sites

These are described in more detail below.

6.3.1 First-Draw Sample Volume Required by the LCR

As is the case in many water systems, the first-draw one-liter (L) sample after a 6+ hour stagnation period, as required by the LCR, may not represent the highest levels of lead in the service line. This sample only represents the water closest to the faucet (typically the first 10-20 feet of the premise plumbing), whereas the stagnant water in the lead piping may not be drawn until much later, depending on the layout of the home plumbing.

As described in Section 4, two lead profiles were generated by performing sequential sampling at two sites, Site A (South Ward) and Site B (North Ward). The first draw sample (of 500 mL) for Site A resulted in 93.1 µg/L total lead; however, lead levels peaked at 399 µg/L in the 15th sample (at a cumulative volume of water of 7.5 L). The lead reached the highest value where the volume of water represents the location of the lead service line. For Site B, the first draw sample (of 500 mL) resulted in 17.5 µg/L of total lead, whereas the lead results peaked with a value of 174 µg/L in the 4th sample (at a cumulative volume of 2.0 L). The lead reached the highest value in the location of the galvanized piping.

It is clear from the sequential sampling that first-draw samples are not likely to capture the highest lead sample.

6.3.2 Error Resulting from Customer Collection of Samples

As per the LCR, the customer is responsible for collecting a sample after 6+ hour stagnation period. This could result in variability of the amount of lead in the sample. Because customers may collect each sample after different stagnation periods or may not sample exactly the same way each time, lead samples could easily show significant variability. Further, the number of required samples has increased over the years from 50 samples every 3 years to 100 samples twice a year. By increasing the number of samples, the potential for variability increases.

6.3.3 Accuracy of Inventory and Confirmation of Sample Sites

Upon review of the City of Newark's historic compliance sampling over the last 20+ years, it is not clear if all homes selected for sampling in some years that were confirmed as sites with lead service lines (i.e. Tier 1 sample sites). The LCR requirements for the sampling pool have been clarified over time and the original Rule did not establish clear guidelines for the site selections. It has not been confirmed if the historic sample sites were Tier 1 sites at the time of each sampling round. Newark has confirmed that their sampling pool in 2017 and 2018 contains only Tier 1 sites.

6.3.4 Proportional Mix of Pequannock and Wanaque Sampling Sites

Upon review of the City of Newark's historic compliance sampling results, it was observed that the compliance sampling program did not proportionally represent both Pequannock-supplied areas and Wanaque-supplied areas in each sampling round. For example, in some sampling rounds, only areas served by Pequannock were sampled, and in other rounds, only areas served by Wanaque were sampled. This would influence the ability to identify clear data trends, such as increasing lead levels in the system.

Section 7

Desktop Corrosion Control Evaluation

This section presents an overview of available corrosion control treatment (CCT) methods for lead. In addition, this section summarizes theoretical lead solubility modeling of carbonate and phosphate-based chemistry.

7.1 Theoretical Lead Solubility Modeling

The 1991 Lead and Copper Rule (and subsequent revisions) stipulates that public water systems evaluate the effectiveness of each of the following treatments (or, if appropriate, combinations of the following treatments) to identify the optimal corrosion control treatment for that system:

- (i) Alkalinity and pH adjustment;
- (ii) Calcium hardness adjustment; and
- (iii) The addition of a phosphate or silicate-based corrosion inhibitor at a concentration enough to maintain an effective residual concentration in all test tap samples.

Guidance manuals to support implementation of the LCR requirements were developed by USEPA initially in 1997, revised in 2003, and most recently revised in 2016 (US Environmental Protection Agency, 1997).

Subsequent to the promulgation of the LCR and designation of CCT methods, research and full-scale system experience identified that plattnerite (PbO_2), an insoluble Pb(IV) mineral, can form under certain highly oxidative conditions found in distribution systems. Pb(IV) was discovered in the Newark system, along with Pb(II) mineral phases, as reported in Section 5. Pb(II) is discussed in Section 7.1.2 below. Pb(IV) is discussed in detail in Sections 5 and 6 of this report.

7.1.1 Calcium Hardness Adjustment

Since the time of promulgation of the LCR, it has been recognized that calcium hardness adjustment is not an effective form of corrosion control as research has shown that calcium carbonate films only rarely form on lead and copper pipe. As such, calcium hardness is not considered in this report.

7.1.2 Alkalinity and pH Adjustment

Changing the alkalinity and pH causes the formation of insoluble lead/hydroxide/carbonate compounds on the interior wall of water pipes. This process approach binds the lead into complex mineral films of limited solubility, thereby reducing dissolved lead concentrations. In raising the pH, the hydroxide (OH^-) and carbonate (CO_3^{2-}) concentrations are increased. These ions then bind with the lead to decrease lead solubility. In low alkalinity waters with a pH range of 9 to 10, it is generally anticipated that the following insoluble Pb(II) carbonate mineral phases will form:

- Cerussite (PbCO_3) (simple lead carbonate)
- Hydrocerussite ($\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$), or
- Plumbonacrite ($\text{Pb}_{10}(\text{CO}_3)_6(\text{OH})_6\text{O}$)

7.1.3 Phosphate-based Corrosion Inhibitors

Phosphate-based corrosion inhibitors have been widely used to control lead and copper release. Within the general classification of phosphate compounds, there are two primary types – **orthophosphates** and **polyphosphates**. There are also products termed **blended phosphates** that consist of blends in various proportions of ortho- and poly-phosphates. Orthophosphate inhibitors form relatively insoluble compounds with Pb(II) which, in turn, render the lead relatively immobile. This occurs through the reaction of lead with the orthophosphate to form very insoluble compounds such as hydroxypyromorphite ($\text{Pb}_5(\text{PO}_4)_3\text{OH}$) and tertiary lead orthophosphate ($\text{Pb}_3(\text{PO}_4)_2$).

The literature and actual operating experience establish that orthophosphate (not polyphosphate) is the active form of the corrosion inhibitor that effectively reduces lead solubility. Reiber et al., states, “Almost all studies agree that orthophosphate is, within a narrow pH window, an effective corrosion inhibitor for both lead and copper surfaces. There is little evidence to suggest that pure polyphosphates play a role in corrosion inhibition.” (Reiber, 1991)

Several factors govern the effectiveness of orthophosphate addition – namely the pH, dissolved inorganic carbon (DIC), and orthophosphate dosage. The optimum pH for lead solubility reduction by orthophosphate depends on the background DIC/alkalinity of the water. Solubility models predict that the maximum benefit from orthophosphate inhibitors will occur in the lowest alkalinity waters (Reiber, 1991).

7.1.4 Silicate-based Corrosion Inhibitors

Silicate-based corrosion inhibitors are limited in terms of the information available on their use and effectiveness. Sodium silicate (Na_2SiO_3) is used primarily as a sequestering agent for the control of iron and manganese, but has been used with varying degrees of success in controlling lead and copper corrosion.

Little research and field information are available to prove the effectiveness of silicate-based inhibitors for lead control. The limited work that has been done has shown that a relatively high concentration of silicate is needed (around 20 mg SiO_2/L), and that it may take months to see any reduction in lead concentrations (American Water Works Research Foundation and DVGW-Technologiezentrum Wasser, 1996). The mechanism by which sodium silicate works to prevent lead from leaching into the water is not known. Speculation ranges from the formation of a passivating compound on the pipe wall to adsorption of lead ions (as well as other ions such as iron and manganese) to the surface of a silicate film on the pipe wall (American Water Works Research Foundation and DVGW-Technologiezentrum Wasser, 1996).

The inhibitory effects on corrosion scale formation and surface roughness of pipe materials common to drinking water distribution systems with and without exposure to phosphorus- and silicon-based inhibitors were investigated using X-ray photoelectron spectroscopy (XPS) and

profilometry in a 2008 research project. (Water Research Foundation, 2008). XPS was used to identify various forms of lead corrosion scales to determine the controlling solid phase(s). No Pb-Si complexes were found in the scales when silicates were used. The researchers also noted that, after a thorough review of lead complex formation literature, there was no evidence to suggest complexation of lead and silica.

Notwithstanding the unknown protection mechanism, it is reported that for passivation of lead, the required dose of sodium silicate solution is typically much higher (20–30 mg/L as sodium silicate) than that of the phosphate-based inhibitors (1–2 mg/L as P) (AWWA, 2017).

Because silicates are highly alkaline, the primary corrosion protection offered by silicates is believed to be the increase in pH that comes from the addition of the chemical, particularly in low alkalinity waters. Increased pH is beneficial as it promotes formation of low solubility lead carbonate mineral phases as discussed above. However, it would likely be more economical to increase pH using standard chemicals such as lime or sodium hydroxide.

The WRF study on corrosion inhibitors detected silica in the scale of 50% of the coupons exposed to a silicate inhibitor (Water Research Foundation, 2008). The scale on all coupons exposed to the silicate inhibitor appeared denser than other scales formed in the presence of phosphate or carbonate inhibition. The study noted that an advantage of silicate addition may be in the promotion of a denser amorphous silica layer.

The silicate in sodium silicate solutions carries a negative charge and will, in theory, migrate to anodic areas where it can react with metallic ions. One manufacturer of sodium silicate (PQ Corporation) reported that monomeric silica represented by SiO_3^{-2} is adsorbed onto pipe surfaces at anodic areas, forming a thin monomolecular film on the interior of the pipe, preventing further corrosion at the anode (Water Research Foundation, 2008). This work included microscopic and X-ray examination of the film formed at the metal surface, which showed it had two layers, with most of the silica in the surface layer adjacent to the water. This work also reported that naturally occurring silica in the form of SiO_2 probably reacts with cations in bulk water and may not be effective in reacting with pipe surfaces.

As discussed in Section 5, a silica crust (SiO_2) was found on all three lead service lines examined from the Newark system. The silica crust was found to be relatively porous and therefore not acting as an effective barrier against the outward flux of lead released from the pipe as the passivating lead layers (mainly plattnerite and hydrocerussite) were found behind the silica crust.

In summary, no evidence has been found to demonstrate that silicates form insoluble (or low solubility) phases with lead to immobilize lead into protective pipe scales. The likely benefit of silicates is the resulting boost in pH, which promotes the formation of lead carbonate scales, or in the formation of a dense silica scale to form a barrier against lead release.

7.2 Theoretical Lead Solubility Modeling

Equilibrium solubility models can be useful to evaluate corrosion characteristics of water and to predict changes in those characteristics with changes in water quality conditions and treatment. However, solubility models are dependent upon the accuracy of the *characterization of the*

solids and complexes considered, the accuracy of the thermodynamic constants used for the various chemical reactions, and do not take into account important aspects of kinetics, interaction with organic materials or tuberculation/ corrosion products, and post-treatment deposition of various scales (such as compounds of iron, calcium and manganese). The most widely-used solubility models are based on Pb(II) mineral phases – either carbonate or phosphate – controlling lead solubility.

As presented in Section 5, the scale analyses conducted by the EPA revealed that Pb(II) chemistry is only partially applicable to Newark's current conditions, as Pb(IV) solids are also present in the pipe scales. All three locations analyzed showed both Pb(II) and Pb(IV) scale deposits, with the outermost layers being primarily hydrocerussite (Pb(II)), with cerussite (Pb(II)) and plattnerite (Pb(IV)) also present.

Work by Schock and Gardels in 1983 identified a discrepancy in lead solubility data when compared with predicted solubility curves. At the time, it was believed that the discrepancy was a result of experimental and theoretical errors and to the possible presence of Pb(IV) compounds in chlorinated waters. Subsequent research by Schock, published in 1990 and 1996, indicated that the discrepancy was likely due to the potential formation of Pb(IV) compounds in drinking water distribution systems (Boyd, et al., 2008) which are not represented by the Pb(II) solubility models.

CDM Smith often uses the Water!Pro Corrosion Control and Treatment Process Analysis Program (Water!Pro), supplemented by published lead solubility diagrams (American Water Works Research Foundation and DVGW-Technologiezentrum Wasser, 1996)), to evaluate theoretical lead solubility and effectiveness of alternative corrosion control treatment options. As with most other equilibrium solubility models, Water!Pro is based on Pb(II) solids controlling lead solubility.

For the Newark desktop analysis, the Water!Pro model was used as a guide to provide information to supplement the decision-making process, recognizing the limitations of its applicability given the scale analysis findings of mixed Pb(II) and Pb(IV) mineral phases. The model analysis is presented herein to evaluate alternatives to reduce lead solubility based on anticipated future conditions being dominated by Pb(II) as the controlling lead species. As discussed in this report, it is not viable to attempt to maintain Pb(IV) as the controlling oxidation state given the current challenges with achieving simultaneous compliance with the Stage 2 Disinfection Byproducts Rule.

The model analysis in no way predicts the transition from Pb(IV) to Pb(II), or the reduction in lead solubility from current conditions to the future proposed scenarios, due to the limitations of the model. It is also important to note that the theoretical Pb(II) solubility values predicted by the model are **not** lead concentrations that would be measured at customers' taps. In practice, lead levels at the customers' taps are often lower than predicted. In the field, sampling rarely occurs under ideal conditions of true chemical equilibrium as assumed by the solubility models. In addition, some water constituents that may affect lead corrosion in drinking water may not be adequately represented in the model, as discussed above.

7.3 Model Inputs

The historic water quality and chemical usage for Newark is presented in Section 3. **Table 7-1** below summarizes the key water quality parameters, by season, that were used as input for the Water!Pro model.

Table 7-1 – Model Input of Seasonal Water Quality Parameters

Source Water	Newark - Pequannock Reservoir			
Scenario #	1	2	3	4
Season	Summer (Jun-Aug)	Fall (Sept-Nov)	Winter (Dec-Feb)	Spring (Mar-May)
Water Quality Input				
TDS, mg/L ^[1]	118.0	116.0	109.3	118.0
Calcium, mg/L Ca ²⁺	10.4	10.0	9.5	9.5
Total Alkalinity, mg/L as CaCO ₃	23.8	24.6	21.7	19.5
pH	6.7	6.6	6.6	6.5
Field Water Temperature, deg. C	21.8	13.8	6.5	13.3
Cl ⁻ , mg/L ^[2]	30.8	34.7	37.1	33.6
SO ₄ ²⁻ , mg-/L ^[3]	10.7	10.1	11.5	11.3
Mg ²⁺ ^[4] , mg/L	4.4	4.6	4.4	4.1

^[1] 9 monthly averages from the 'Optimal Corrosion Control Treatment Recommendations Dec 2017' report.

^[2] 16 samples from 1994-2017 from NJDEP Drinking Water Watch

^[3] 22 samples from 1994-2017 from NJDEP Drinking Water Watch

^[4] 17 samples from 1994-2017 from NJDEP Drinking Water Watch – Delivered Water

Table 7-2 summarizes the chemical additives used in the Water!Pro model, based on seasonal averages, from the information provided by the Newark plant staff. Sodium hypochlorite was used in the model instead of chlorine gas, as the City of Newark will be switching their current feed system to a sodium hypochlorite feed system in the near future.

Table 7-2 – Model Input of Seasonal Chemical Addition Parameters

Source Water	Newark – Pequannock WTP			
Scenario #	1	2	3	4
Season	Summer (Jun-Aug)	Fall (Sept-Nov)	Winter (Dec-Feb)	Spring (Mar-May)
Chemical Addition Input				
100% Hydrated Lime (Ca(OH) ₂), mg/L	3.3	4.2	3.2	2.7
Clarion (0.5%Acid Alum*14.3H ₂ O), mg/L	9.0	9.8	9.9	9.4
Sodium Hypochlorite (NaOCl), mg/L as Cl ₂	3.5	3.1	2.7	2.3
PACI (12.2% Al, 70% Basicity), mg/L	1.9	2.5	1.8	1.8

7.4 Lead Solubility – Existing Conditions

As noted above, the current Newark conditions cannot be modeled with the Water!Pro model because the model is based on Pb(II) minerals (either carbonate or phosphate) being the controlling lead phase whereas both Pb(II) and Pb(IV) were found in the Newark system scales. However, knowing that it is impractical to maintain the Pb(IV) scales to control lead, any future corrosion control treatment will involve either carbonate or phosphate chemistry. As such, the model was utilized to illustrate the **theoretical** lead solubility for various carbonate and phosphate conditions.

The initial step was to estimate the theoretical lead solubility under current conditions, assuming only Pb(II) carbonate solids are controlling lead release. This was then compared to the theoretical lead solubility for: (1) optimized pH/alkalinity conditions, and (2) with the use of orthophosphate.

Newark's system operated with an average finished water alkalinity that ranged from 22.0 mg/L to 24.9 mg/L from 2015-2018, with an average of 23.5 mg/L as CaCO₃. From 2015-2018, the pH ranged from 6.9 to 7.3. The dissolved inorganic carbon (DIC) level was calculated as 8.2 to 9.7 mg/L as C.

The theoretical lead solubility of Newark's current system is presented in **Table 7-3**, and seasonally ranges from 207 µg/L to 437 µg/L of lead.

Table 7-3 – Theoretical Lead [Pb(II)] Solubility by Season (with Sodium Hypochlorite)

Season	pH 2018 operating range	Theoretical Lead [Pb(II)] Solubility (µg/L)
Summer	6.72 – 7.3	.437 – 259
Fall	6.72 – 7.3	355 – 209
Winter	6.72 – 7.3	352 – 207
Spring	6.72 – 7.3	402 – 209

These values were then used as a “baseline” for comparison to alternatives aimed at reducing theoretical Pb(II) solubility, and thus achieving lower lead levels at the tap.

7.5 Lead Solubility – Modified CCT Alternatives

Several alternatives were evaluated to determine their impact on the theoretical Pb(II) solubility including:

- Increased finished water pH
- Addition of orthophosphate

The following discussion summarizes the results.

7.5.1 Increased Finished Water pH

Both lime and sodium hydroxide were evaluated for pH adjustment. Both chemicals provided the same reduction in theoretical lead solubility, therefore only the results for lime are presented

here. **Figure 7-1** demonstrates the theoretical Pb(II) solubility for the summer water quality parameters as pH increases. Similar results were observed under all seasonal conditions. As shown in **Figure 7-1**, the theoretical Pb(II) solubility significantly decreases as pH is increased to approximately 9.5. A pH level of about 9.0 – 9.5 would theoretically be needed to optimize carbonate scale formation and maintain dissolved lead levels at acceptable values.

Increasing pH to 9.0 – 9.5 reduces lead solubility, but will likely result in increased disinfection byproduct levels. Newark is currently challenged with compliance of the Stage 2 Disinfectant and Disinfection Byproducts Rule for both trihalomethanes (THMs) and haloacetic acids (HAAs). It is not advisable for Newark to raise the pH to optimize carbonate scale formation at this time with the current treatment processes, open water reservoir, and disinfection chemicals. A more systematic and comprehensive evaluation to control disinfection byproduct formation and achieve effective primary disinfection would be needed.

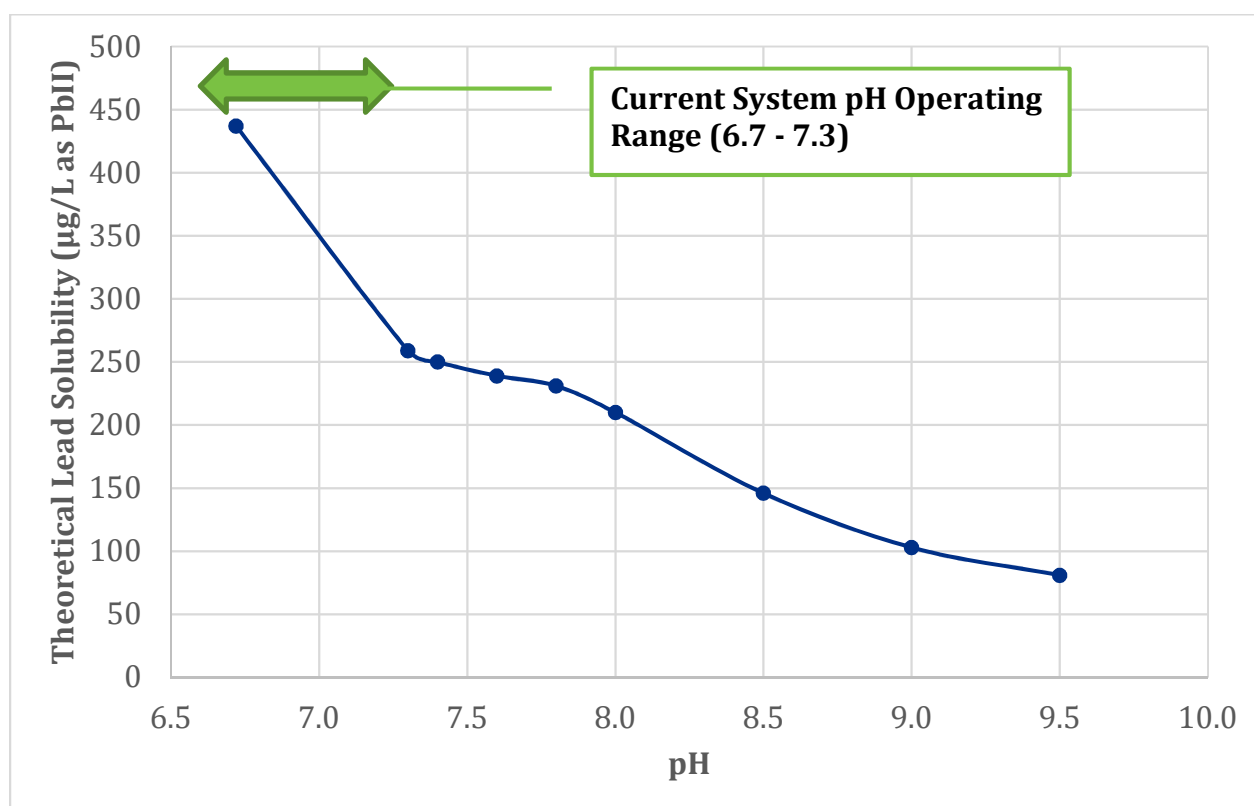


Figure 7-1 – Effect of pH Adjustment on Theoretical Pb(II) Solubility

7.5.2 Addition of Orthophosphate

The use of orthophosphate has been a successful approach for minimizing corrosion of lead-containing materials (USEPA, 1993). Solubility models and experience indicate that the optimal pH for orthophosphate scale formation is between 7.2 and 7.8 (US Environmental Protection Agency, 2016).

Using the seasonal water quality data in Table 7.1, theoretical lead solubility values were modeled for various orthophosphate concentrations at the current baseline average pH of 7.1, as well as at

pH of 7.3 and 7.5, to cover the anticipated range of optimal pH conditions. Results at pH 7.8 were theoretically the same as at pH 7.5.

Figure 7-2 presents theoretical lead solubility across a range of orthophosphate dosages (0.5 to 3.5 mg/L as PO₄) and pH levels for summer conditions. Similar results were achieved for all seasonal conditions showing a reduction in lead solubility. Movement from one place on the graph to another with lower lead solubility is expected to result in reduced concentrations of soluble lead in the field.

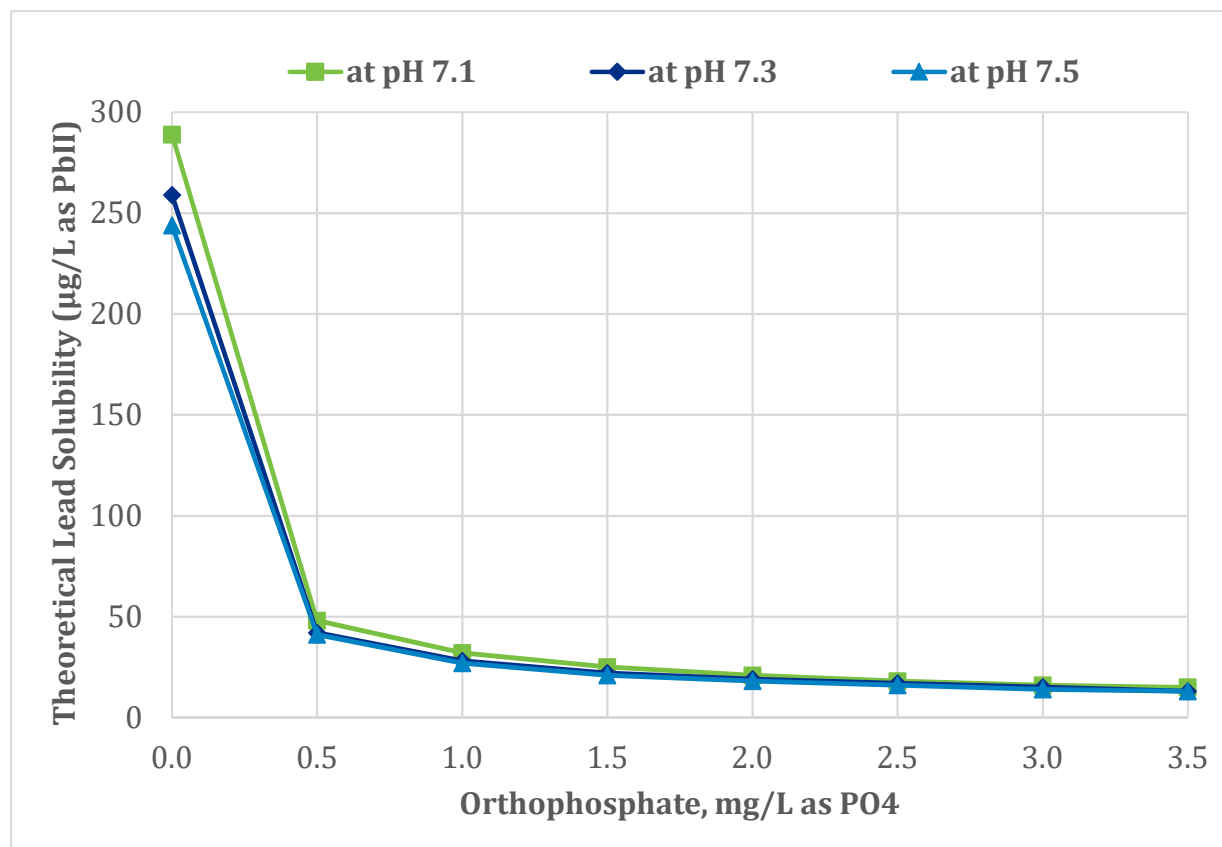


Figure 7-2 – Effect of Orthophosphate on Theoretical Pb(II) Solubility at Varying pH Values in Summer

Overall, the results show that orthophosphate can significantly reduce theoretical lead solubility in the City of Newark's drinking water considering only Pb(II) chemistry. For example, as shown on **Figure 7-2**, at an average pH of 7.3, lead solubility as Pb(II) is theoretically reduced by 83% with the first 0.5 mg/L of orthophosphate as PO₄ and by 89% when orthophosphate is increased to 1.0 mg/L as PO₄.

Although benefits to reducing lead solubility continue with increasing PO₄ dose, as demonstrated in **Figure 7-2**, the incremental reduction in theoretical Pb(II) solubility becomes less significant with dosages greater than 1.0 mg/L as PO₄. However, this does not account for particulate lead that may enter the system as a result of the instability of the legacy Pb(IV) and Pb(II) carbonate scales. It is not known what level of orthophosphate addition would be required to control the

distribution and mobility of lead particles. However, full-scale experience from other systems with lead release conditions has shown that orthophosphate doses in excess of that theoretically required were necessary. The addition of orthophosphate can readily lower dissolved lead levels, but total lead concentrations can persist at elevated levels for a longer period of time (Giammar, 2017). In comparing the pH adjustment alternative to the orthophosphate option for controlling soluble Pb(II) lead, the theoretical dissolved Pb(II) concentration with pH adjustment to 9.5 without orthophosphate addition is almost three times higher than that with 1.0 mg/L of orthophosphate as PO_4 at a pH of 7.3. This does not account for any impact of legacy Pb(IV) solids in the system. It is important to recognize that theoretical lead solubility modeling only considers Pb(II) mineral phases to control soluble lead. Elevated lead concentrations at the tap can occur due to the presence of insoluble lead particles dislodged from lead pipe, solder or brass plumbing fixtures. Elevated lead concentrations due to particulate lead cannot be predicted.

As discussed in Section 7.1.4, the current practice of sodium silicate addition provides an increase in pH, which may be more economically achieved by the addition of a less costly alkaline chemical such as lime or sodium hydroxide. Because the Pequannock WTP currently uses lime, the amount of lime needed to increase pH without the use of sodium silicate was examined. It is recognized that the existing lime system has limitations that would need to be addressed should sodium silicate addition be discontinued in the future.

Table 7-4 presents an estimate of the amount of hydrated lime needed to accompany various amounts of added orthophosphate (without the addition of sodium silicate) to achieve finished water pH conditions of 7.2 and 7.4. The addition of lime increases with the addition of orthophosphate since orthophosphate is an acid.

Table 7-4 – Estimated Theoretical Lime Dose to Maintain Desired pH for Orthophosphate

Season	Dose (mg/L as PO_4)	Hydrated Lime Dose Needed to Achieve Target pH (without Silicate) (mg/L)	
		7.2 pH	7.4 pH
Summer	0.5	7.3	8.4
	1.0	7.6	8.8
	2.0	8.3	9.7
	3.0	9.2	11.1
Fall	0.5	10.5	12.1
	1.0	10.8	12.4
	2.0	11.6	13.3
	3.0	12.4	14.2
Winter	0.5	10.7	12.3
	1.0	11.0	12.7
	2.0	11.7	13.5
	3.0	12.4	14.4
Spring	0.5	11.2	12.5
	1.0	11.5	12.9

Season	Dose (mg/L as PO ₄)	Hydrated Lime Dose Needed to Achieve Target pH (without Silicate) (mg/L)	
		7.2 pH	7.4 pH
	2.0	12.2	13.8
	3.0	13.0	14.8

As discussed in **Section 3.3.1**, buffer intensity is more greatly influenced by pH than alkalinity. Waters with a pH outside of the range of 8.0 and 8.5 (including the optimal pH range for orthophosphate of 7.2 to 7.8), even with low DIC, will have higher buffer intensity and should exhibit less variability in pH in the distribution system. **Figure 7-3** shows the impact of pH and alkalinity on buffer intensity for the Pequannock finished water, including the intended pH of 7.4 with the future addition of orthophosphate. As can be seen from the figure, at a constant pH, the buffering capacity remains consistent with increasing alkalinity. However, buffer intensity decreases significantly with increasing pH.

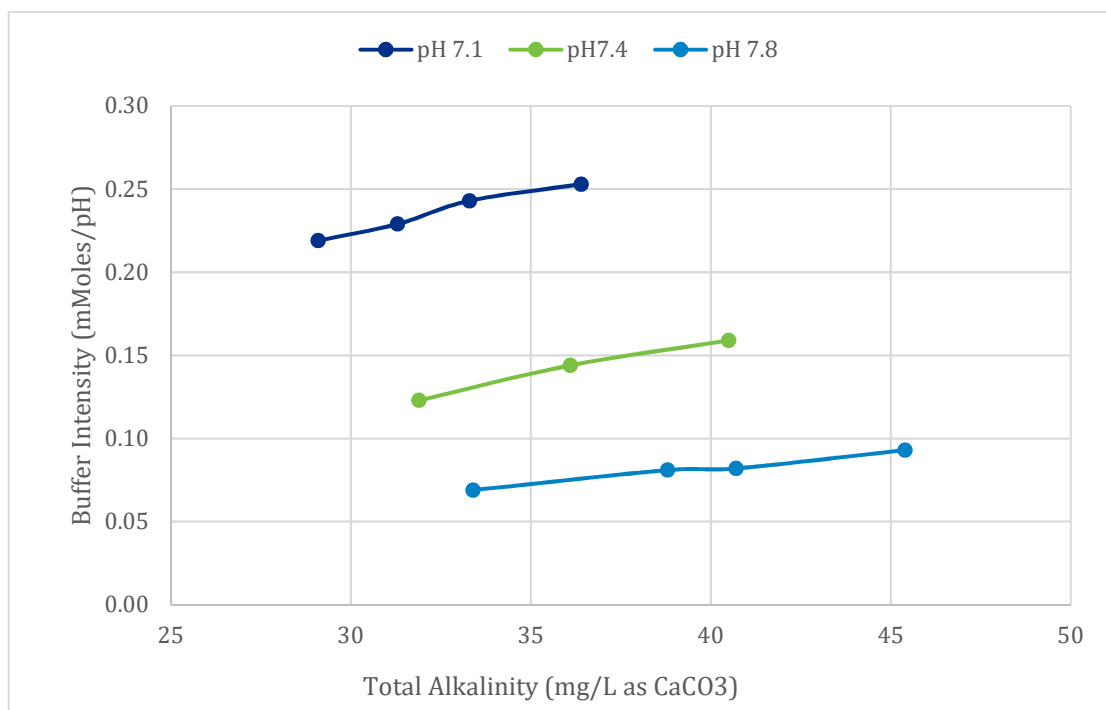


Figure 7-3 – Buffer Intensity as a Function of Alkalinity and pH

7.5.3 Other Alternatives Not Considered

As discussed in Section 7.1, the Lead and Copper Rule, as well as the recent EPA OCCT Evaluation Technical Recommendations for Primary Agencies and Public Water Systems (US Environmental Protection Agency, 2016), identifies three available corrosion control treatment methods: (1) pH/alkalinity/DIC adjustment, (2) phosphate-based corrosion inhibitors, and (3) silicate-based corrosion inhibitors. The evaluation presented above considered the first two methods. As

discussed in Section 7.1, sodium silicate has not been proven to be effective for controlling lead corrosion. Other than its ability to increase pH and encourage formation of carbonate scales at higher pH conditions, it provides only a porous silica crust on the pipe that does not appear to prevent lead release as no Si-Pb crystalline compounds are formed. (see EPA scale analysis in Section 5 and Appendix A). Continuing the use of sodium silicate as the only method for CCT for Newark is not recommended.

Only recently has the formation of the solid phase tetravalent lead (Pb(IV) or PbO₂) been recognized in EPA OCCT Guidance (US Environmental Protection Agency, 2016). Newer research (Schock, 2001) has confirmed that Pb(IV) compounds (e.g., plattnerite) can be the predominant compounds in lead pipe scales under highly oxidative conditions and under low organic matter conditions. (see Pourbaix diagram in Figure 6-1). PbO₂ is extremely insoluble and is very effective in preventing lead from being released to the water. Based on studies performed on systems with known plattnerite scales compared with Pb(II)-based scales, lead levels at the tap and during sequential sampling were lower for the Pb(IV) scales than for the Pb(II) scales (Triantafyllidou, Schock, DeSantis, & White, 2015).

Under high ORP conditions (i.e., high chlorine residual), and in the absence of corrosion inhibitors or other interfering surface deposits, Pb(IV) scales can form on lead pipe surfaces. The predominance of Pb(IV) scales is dependent on ORP (i.e., chlorine residual), pH, and the presence of NOM (Boyd, et al., 2008). As discussed in Section 5.1, the conditions needed for PbO₂ formation may be found in systems that have a high ORP. If the specific water quality conditions are modified, such as decreasing pH and/or reducing chlorine residual which would reduce ORP, the Pb(IV) scale is destabilized and converts back to Pb(II) (Boyd, et al., 2008), and as shown in Figure 6-1. Recent evidence shows that Pb(IV) scales may be more prevalent in systems than previously thought, and may exist at lower chlorine residual levels. The impact pH has on Pb(IV) scales is further discussed in Section 6.2.2 and is illustrated in Figure 6-1.

Because of the importance of pH, maintaining Pb(IV) scales to control lead release is not a realistic option for Newark while simultaneously complying with the Stage 2 Disinfectants and Disinfection Byproducts Rule. In addition, questions remain as to the required chlorine residual that should be maintained in the distribution system and lead service lines for the formation and maintenance of Pb(IV) scales. For this reason, EPA has not adopted Pb(IV) scale formation as an acceptable corrosion control treatment technique at this time.

Section 8

Recommendations

Based on the analysis of the historic lead sampling results presented in Section 2 of the Pequannock and Wanaque water systems, it is clear that the Pequannock system's current CCT has lost its effectiveness while the Wanaque system's CCT has remained effective. The 90th percentile lead level in the Pequannock system slightly exceeded the LCR Lead Action Level of 15 µg/L in 2015 (at 15.8 µg/L) and further increased in 2017 and 2018. The Wanaque system's 90th percentile has remained below the Lead Action Level. Therefore, this section presents recommendations for the City of Newark to improve their corrosion control program in the Pequannock service area only. Both immediate and long-term corrosion control treatment recommendations are provided, as well as interim measures to reduce public health risks until the treatment has time to be effective in reducing lead levels.

The following alternatives were eliminated from further consideration either due to ineffectiveness in reducing lead solubility, or their likely adverse impacts on other water quality goals. The alternatives that were eliminated are discussed in detail in the report sections identified in parentheses below.

- Increase finished water pH to above 9.0 to promote more effective carbonate scale formation (see Section 7)
- Increase finished water pH and ORP for tetravalent lead scale stabilization and maintenance (see Section 5 and Section 6)
- Increase sodium silicate dosing (see Section 6)

The primary recommendation for achieving optimized CCT in Newark's water supply is the addition of an orthophosphate chemical feed system in the Pequannock service area. Details of the proposed system are further discussed in this section the report. The addition of orthophosphate is anticipated to provide reductions in lead levels without expected adverse impacts on other water quality goals, namely compliance with primary disinfection and disinfection byproduct regulations for Newark and its consecutive systems (i.e. Bloomfield, Belleville, etc.). The benefits and constraints of adding an orthophosphate system in Newark's distribution system are noted as follows:

Benefits of Adding Orthophosphate

- Full-scale experience combined with corrosion control theory indicates orthophosphate will effectively reduce Pb(II) lead solubility in Newark's distribution system with a pH between 7.2 and 7.8.
- Scale analysis performed by the EPA shows a breakdown of the existing tetravalent and carbonate scales. Other systems with similar conditions experienced a significant reduction in total lead within a few months of adding orthophosphate.

- Orthophosphate is a common, proven treatment for lead corrosion control in distribution systems in New Jersey and across the country.
- Orthophosphate will reduce duration of elevated lead levels at the tap resulting from soluble and insoluble lead compared with making no system changes and compared with raising the sodium silicate dose.
- Adding orthophosphate does not require significant water quality modifications, such as a high pH or high chlorine residual, allowing for greater opportunity for simultaneous compliance with primary disinfection and disinfection byproduct regulations.
- Orthophosphate is consistent with the corrosion control treatment in Wanaque system, which will equalize the system during periods of blending between the two systems.
- Orthophosphate is widely available and approved for potable water use.

Secondary Impacts and Possible Constraints of Adding Orthophosphate in Newark

- Unknown potential for increase in insoluble lead during the initial passivation phase as the plattnerite scale continues to be unstable and is replaced with a phosphate-based scale. It is unknown if the orthophosphate will initially exacerbate the particulate issue short-term prior to seeing a reduction in lead levels. Point-of-use filters are recommended to reduce customer exposure to lead during this period.
- Adding orthophosphate will increase phosphorus loading in wastewater.
- Zinc concentrations in wastewater sludge will increase if using zinc orthophosphate.
- Adding orthophosphate will have a potential effect of higher phosphates on some industrial users.
- There is a potential for temporary “dirty” water if the system is not sufficiently flushed prior to implementation.
- There is a potential for white cloudy water with orthophosphate concentrations above 3.2 mg/L as PO_4 . (Tesfai, Constanant, & Reibier, 2006)
- There is a potential for stimulating algae growth if orthophosphate gets into an open body of water, such as the Cedar Grove Reservoir.
- Additional building and security will be needed at the Valley Road Rechlorination Station.
- Possible need for a satellite chemical feed system for the City of Pequannock and any other users upstream of the Valley Road Rechlorination Station.

Wanaque CCT

A separate technical memorandum will be provided with a more detailed evaluation of the Wanaque service area as required by the LCR, including an analysis of areas with potential Pequannock/Wanaque blending, sequential sampling, and pipe scale analyses. The results of the

Wanaque evaluation are not expected to impact the studies and recommendations provided in this report. Any area with blending between the two systems that may have an occasional diluted concentration of orthophosphate in the Wanaque system will benefit from orthophosphate dosing in the Pequannock system to strengthen the CCT further.

8.1 Chemical and Orthophosphate Dosage

Orthophosphate (PO_4), commonly used as a corrosion inhibitor for lead and copper control, was evaluated in a desktop study under four seasonal scenarios and was concluded to be effective in reducing the theoretical lead solubility in all four seasons. The results are presented in Section 7. Orthophosphate reduces lead concentrations through the formation of insoluble Pb(II)-PO_4 mineral phases. (DeSantis, Schock, & Bennett-Stamper, Incorporation of Phosphate into Destablized PbO_2 Pipe Scales, 2012)

For the City of Newark, either phosphoric acid or zinc orthophosphate is recommended. Zinc orthophosphate is a liquid that is available in blends that contain various ratios of zinc to orthophosphate. A zinc orthophosphate blend offers the additional benefits of introducing zinc to the distribution system, which can help reduce corrosion in cement-lined pipes in low alkalinity waters, reduce iron corrosion in unlined pipe, and reduce lead release from brass fittings containing lead. Zinc orthophosphate is more dilute than phosphoric acid, requires twice as much storage volume, and is 3 to 5 times more costly than phosphoric acid for the same active PO_4 dose. In addition, zinc orthophosphate adds zinc into the wastewater sludge, which can impact disposal options for the wastewater treatment facility. Each of these chemicals would be effective for Newark's distribution system as the active ingredient, orthophosphate, is the same.

Although CDM Smith's desktop evaluation presented in Section 7 found that a significant reduction in lead solubility can theoretically be achieved with the first 0.5 mg/L of orthophosphate, the solubility model evaluations cannot account for any soluble lead currently being released into the water as a result of the ongoing destabilization of the PbO_2 scale to soluble Pb(II) . To counteract the current lead release issue without delay, it is recommended that orthophosphate treatment in Newark's distribution system gradually increase to a higher passivation dose prior to settling on a maintenance dose. The 2016 EPA OCCT Guidance Manual states that some systems start with a passivation dose 2 to 3 times higher than the target maintenance dose to build up a protective barrier quickly (US Environmental Protection Agency, 2016). In addition, full-scale experience in other systems with PbO_2 scale destabilization has shown that higher orthophosphate doses (3 to 3.5 mg/L as PO_4) have been able to mitigate the lead release in a relatively short period of time (several months). CDM Smith recommends gradually introducing orthophosphate into the distribution system, starting with a dose of 0.5 mg/L as PO_4 as soon as possible and working up to a passivation dose of 3.0 mg/L as PO_4 . The system will be monitored as discussed later in this Section during the implementation of orthophosphate.

As an example of a similar system, Washington, D.C. started adding orthophosphate in August 2004 in the form of phosphoric acid after it was discovered that a change in disinfectant from free chlorine to chloramines reduced ORP converting PbO_2 , an insoluble tetravalent lead compound, to the more soluble Pb(II) carbonate compounds, resulting in lead release into the water. Washington, D.C. slowly increased the dose of the orthophosphate over a two-week period to 3.5

mg/L as PO₄. At that dose, lead levels in the residential lead service lines reduced from 150 µg/L to 15 µg/L in 8 months based on the sequential sampling profiles. (Giani, Keefer, & Donnelly, 2005)

Although either zinc orthophosphate or phosphoric acid would be appropriate and have the same active chemical, Newark has selected to use zinc orthophosphate to be consistent with the treatment used in the Wanaque water system. Proposed storage for zinc orthophosphate with a passivation dose of 3.0 mg/L and a maintenance dose of 1.0 mg/L is provided in **Table 8-1**. Tanks will be double-walled for containment.

Table 8-1 – Initial Tank Sizing for Orthophosphate Feed System

Scenario	Dose (mg/L)	Storage (gallons)	Days of Storage at Average Flow (55 mgd)	Days of Storage at Max Flow (80 mgd)
Initial Passivation Dose (Temporary)	3.0 mg/L	5,000	14 (348 gpd)	10 (506 gpd)
Maintenance Dose (Permanent)	1.0 mg/L	4,000	34.5 (116 gpd)	24 (169 gpd)

A concurrent pipe loop demonstration study is recommended to be performed in parallel with full-scale implementation of the orthophosphate feed system to optimize treatment by studying factors such as pH and dose of the orthophosphate. Details of the recommended pipe loop demonstration study are discussed in Section 8.4.

In dosing orthophosphate, an increase in phosphorous and zinc concentrations will occur in the wastewaters collected in Newark and other communities using the Newark's water. Owners of wastewater treatment facilities that will encounter increased phosphorous concentrations will need to be notified to determine any potential implications to NJPDES permit compliance that may result from the orthophosphate chemical addition.

8.2 Chemical Feed Location Recommendations

Redacted for Privilege

[Redacted content]

Redacted for Privilege

8.3 Distribution System pH Recommendation

Currently, the average pH at the Valley Road Rechlorination Station is approximately 7.1 at the POE into the distribution system. The EPA OCCT Guidance Manual, confirmed by full-scale experience, recommends a pH range of 7.2 to 7.8 for orthophosphate addition (US Environmental Protection Agency, 2016); however, every system is unique with respect to its optimal pH range. With the pH variability known to occur in the City's distribution system, it is recommended that Newark aim to achieve a slightly higher pH, in the interim, of approximately 7.3 to 7.4 leaving the Valley Road Rechlorination Station to stay above pH 7.2 in the far reaches of the distribution system. At a pH below 7.2, the orthophosphate will be slower to react and will not be as effective in reducing lead solubility. Newark has provided a plan to NJDEP to meet simultaneous compliance of primary disinfection, disinfection byproducts and corrosion control. If pH must remain low at the Pequannock WTP for compliance reasons, a satellite sodium hydroxide chemical feed system can be installed at the Valley Road Rechlorination Station to raise pH in the distribution system to improve corrosion control.

In the long-term, if Newark can improve its removal of disinfection byproduct precursors and find a suitable means of assuring primary disinfection, then pH can be increased further to a more effective range for orthophosphate, likely between 7.5 and 7.8. The optimal pH range for Newark's water can be evaluated in the loop study discussed in Section 8.4.

To achieve the recommended pH values of 7.3 to 7.4 without sodium silicate in all seasons, a lime dose of approximately 12 to 15 mg/L would be required. It is recommended that sodium silicate continue to be used as a pH adjustment chemical until the lime feed system is operated at these higher dosages. Sodium silicate use should also be continued until the pilot loop study can evaluate whether there will be any negative impacts of discontinuing the silicate application in the distribution system.

Maintaining a consistent pH is as important as the actual pH level itself. In the month of July 2018, daily pH at the Valley Road Rechlorination Station fluctuated between pH 6.29 and 7.65. This is an extreme variation in pH values over a 31-day period. Furthermore, the pH range throughout the distribution system is even more extreme than the values measured at the distribution system POE. As of the finalization of this report in March 2019, Newark has stabilized pH at the Pequannock WTP. If variations are experienced in the distribution system or if the pH is

consistently below the optimal pH range for zinc orthophosphate, it is recommended that Newark install a satellite sodium hydroxide feed system.

8.4 Demonstration Pipe Loop Study

To optimize the addition of orthophosphate to Newark's distribution system, a pipe loop demonstration study should be performed. However, in the interest of public health protection, it is not recommended that full-scale implementation of orthophosphate addition be delayed until after the pipe loop study is completed. In parallel with full-scale implementation of orthophosphate addition, the pipe loop study would evaluate parameters such as:

- Optimal PO₄ dose
- Optimal pH
- Change in pH adjustment chemical (i.e., replacing sodium silicate with an alternative alkaline chemical)

A protocol for the pipe loop study will be developed in conjunction with Newark and provided to NJDEP for review prior to commencing the study. In general, the study could include one rack of three or four pipe loops to be installed at the Pequannock WTP. Each loop would contain a section of excavated lead service line from Newark's distribution system. A portion of each LSL would also be sent to EPA for analysis of the pipe scales to document baseline conditions. Scale analyses would then be conducted on the pipe segments within the loops later in the study to correlate actual scale deposits with the water chemistry conditions. During development of the study protocol, the need to condition the pipe segments at the start of the study using Newark's current finished water would be determined. If conditioning is performed, then, after a short period of initial conditioning, all but one loop would be modified to evaluate the different parameters enumerated above. The remaining pipe loop would continue to represent existing water chemistry conditions as a "control." Sampling is expected to include total and dissolved lead, pH, ORP, chlorine, alkalinity, orthophosphate residual, silica residual and aesthetic water quality parameters such as iron and manganese. A detailed sampling plan would be prepared as part of the study protocol development.

It was confirmed with the EPA in September 2018 that there has not been a successful pipe loop study involving excavated lead pipe containing tetravalent lead scales that have returned to "existing conditions" after a period of conditioning. Once lead pipes with tetravalent lead scales are excavated and disturbed, they continue to behave erratically with an increased release of particulate lead. For this reason, the incorporation of a conditioning period (and the duration of that period) would be evaluated as part of the study protocol development. It may be that, instead of running an extended conditioning period for the loops, CCT modifications will be introduced while the pipes are releasing high levels of particulate lead. CCT solutions that are effective for such a "worst case" condition in the pipe loop study would be anticipated to be effective in the distribution system under the same water chemistry conditions.

As mentioned in Section 5, additional pipes in the West Ward, Central Ward and East Ward are recommended to be excavated and sections sent to the EPA for scale analysis and comparison with the scales already analyzed.

8.5 Implementation Schedule

Newark is proceeding with procurement and construction of a temporary feed system to expedite the dosing of the orthophosphate in the drinking water. It is estimated that the orthophosphate system could be installed and operating by the second quarter of 2019 with the construction of a temporary feed system.

Anticipated completion schedule for efforts related to this improvement project include:

- 4-6 weeks for design and submission of a permit application to NJDEP
- 2-4 weeks for NJDEP review and approval of a Bureau of Safe Drinking Water Permit
- 3-4 months for procurement and construction (providing 8-12 weeks for tank and control panel lead time from approved shop drawings)
- 4-6 weeks installation and operation

It is anticipated that the pipe loop study could be placed into operation prior to the start-up of the proposed orthophosphate system. During this time, the initial introduction of orthophosphate into the lead pipes can be closely monitored to better predict anticipated behavior in the distribution system prior to introducing to the full Pequannock supply.

The permanent system will include buried permanent tanks and require a site plan approval from Montclair. It will be constructed while the temporary system is continuously feeding orthophosphate. The cost of the permanent orthophosphate system as described herein is estimated to be approximately \$800,000 including engineering, materials, labor and equipment. This assumes that the bulk storage tank would be outside in a vault and not housed in a building.

8.6 Monitoring During Implementation

To monitor changes in water chemistry due to the full-scale addition of orthophosphate in the distribution system, it is recommended that a targeted monitoring program be developed and executed. The purpose of the monitoring program is to assess the progression of orthophosphate residual levels in the system, as well as to determine if any adverse water quality effects are occurring as a result of the change in treatment. It is anticipated that sampling would be conducted monthly or more frequently as lead concentrations decrease and stabilize. Flowing samples would be collected from routine coliform sampling sites and analyzed for parameters such as pH, alkalinity, chlorine residual, ORP, color (apparent), turbidity, iron (total and dissolved), manganese (total and dissolved), coliform, HPC, silica and orthophosphate residual. First-draw tap sampling, as well as sequential sampling (discussed below), would be performed periodically at homes with lead service lines selected from the sampling pool for LCR compliance.

In addition, Newark's Water Quality Parameter Sampling Plan will be updated to include monitoring of orthophosphate residual, as well as continuing to monitor pH and chlorine residual. The results from the sampling will be reviewed on an ongoing basis to monitor changes in the distribution system and the sampling program (and treatment) will be adjusted, as necessary.

8.6.1 Sequential Sampling – Before and During Implementation

It is recommended that Newark perform additional sequential sampling to evaluate conditions in the wards not yet tested. This would include the West Ward (Pequannock-supply), Central Ward (potential mix of both Pequannock-supply and Wanaque-supply), and the East Ward (Wanaque-supply). In addition, it is recommended that, as part of Newark's monitoring plan, sequential sampling (measurement of lead profiles), as presented in Section 4, continue to be performed after orthophosphate addition is implemented. The sequential sampling would be performed at homes with lead service lines and lead solder to evaluate the effectiveness of the orthophosphate in reducing dissolved and particulate lead concentrations throughout the service line, including all contributing factors. It is recommended that such sequential sampling be performed at a couple of homes that are easily accessible and will remain with a lead service line for at least the next year. Sampling would be performed at the select homes prior to commencing dosing of orthophosphate and then once every month after orthophosphate is implemented until the lead results stabilize.

8.7 Additional Recommendations

The following are additional recommendations for a holistic approach to improving Newark's water quality.

8.7.1 Short-Term Recommendations

As indicated in this report, there is evidence that protective lead scales that have formed on lead service lines and lead components within premise plumbing in the Newark distribution system have been destabilizing and are porous, allowing lead to be released into the drinking water. Health risks exist for customers with lead service lines and for customers with premise plumbing components that contain lead, such as lead solder, galvanized plumbing and/or brass fittings with lead content. Health risks are greatest for infants, young children, pregnant women and adults with kidney problems or high blood pressure.

The EPA guide, Implementing the Lead Public Education Provision of the Lead and Copper Rule, dated June 2008, should be used as guidance for providing public education and to reach the most vulnerable populations. Other resources are available from the American Water Works Association and the Lead Service Line Replacement (LSLR) Collaborative.

For customers in Newark, utilization of point-of-use filters is the recommended approach to minimize lead exposure through the removal of particulate lead. Filters are recommended until the new orthophosphate system can substantially decrease both dissolved and particulate lead prior to and during the initial passivation period of the orthophosphate. Filters are recommended to help protect customers both in homes with lead service lines and in homes with interior plumbing that contain lead solder, galvanized piping or brass fittings with lead content. Filters are recommended over promoting flushing of premise plumbing since, at this time, the scales are unstable and can be easily disturbed potentially releasing particulate lead during flushing. Point-of-use filters should be NSF 53 and NSF 42 certified for lead removal (NSF/ANSI 53: Drinking Water Treatment Units - Health Effects).

If Newark provides residents with point-of-use filters, the program should provide specific guidance to the customers regarding replacement of the filters at the frequency recommended by

the manufacturer. Risk of contamination can be increased if filters are not properly maintained and replaced regularly.

It is noted that it is expected that Newark will continue to exceed the Lead Action Level until the orthophosphate is dosed at the Valley Road Rechlorination Station and has had time to passivate the system and build a protective barrier to prevent lead from leaching into the water.

8.7.2 Long-Term Recommendations

In considering a holistic approach to achieve simultaneous compliance with all drinking water regulations, it is recommended that Newark evaluate alternatives for the following process modifications:

- **Stabilization of pH in the distribution system.** Stabilizing the pH will help improve water quality. Stabilization may include upgraded chemical feed equipment and monitoring at the Pequannock WTP, pH adjustment at the Valley Road Rechlorination Station, and/or improved monitoring and flushing in the distribution system to maintain a consistent pH from the North Ward to the South Ward.
- **Removal of disinfection byproduct precursors.** Improving filter performance and/or the addition of a clarification process would reduce the organic carbon concentration during treatment and help Newark achieve compliance with the Stage 2 Disinfection Byproducts Rule. Newark has submitted a plan to NJDEP to reduce disinfection byproduct precursors. The upgrades are planned to be in operation in April 2019.
- **Utilizing an alternate primary disinfectant.** An alternate primary disinfection process, such as ozone, may help Newark meet primary disinfection requirements as well as reduce disinfection byproduct formation.

8.8 Impacts on Consecutive Systems

As part of the changes to the water system, Newark will coordinate with any other townships that receive water from the Pequannock supply. Pequannock Township receives water upstream of the proposed orthophosphate addition while all other systems are fed downstream of the proposed orthophosphate addition location. Newark has reviewed the proposed changes to the CCT inhibitor and pH adjustment with the Pequannock Water Department. . The need for a satellite orthophosphate feed system will be evaluated and discussed with the Pequannock Water Department, however, the Pequannock Water Department currently does not have any lead issues.

Newark's consecutive systems downstream of the Valley Road Rechlorination Station are anticipated to benefit from the changes being proposed to the CCT at the Pequannock WTP. The following summarizes the anticipated impact to each system:

- **Belleville Water Department** – will transition from sodium silicate to orthophosphate simultaneously with Newark. The transition will be coordinated to encourage Belleville to flush the mains prior to the transition to remove sediment in the pipe and during the transition to help passivate the system. If the dose of orthophosphate from Newark is diluted, a satellite feed system for Belleville may be recommended.

- Bloomfield Water Department – will transition from sodium silicate to orthophosphate simultaneously with Newark. The transition will be coordinated to encourage Bloomfield to flush the mains prior to the transition to remove sediment in the pipe and during the transition to help passivate the system. If the dose of orthophosphate from Newark is diluted, a satellite feed system for Bloomfield may be recommended.
- City of Elizabeth (c/o New Jersey American Water – Liberty) – already doses orthophosphate, which is currently supplied from the Wanaque source. The CCT proposed at the Pequannock supply will not have an impact on the City of Elizabeth system.
- Nutley Township – will transition from sodium silicate to orthophosphate simultaneously with Newark. The transition will be coordinated to encourage Nutley to flush the mains prior to the transition to remove sediment in the pipe and during the transition to help passivate the system. If the dose of orthophosphate from Newark is diluted, a satellite feed system for Nutley may be recommended.
- All other interconnections with Newark are either on the Wanaque Gradient or used on an emergency basis only. Most of the systems with emergency interconnections with Newark utilize an orthophosphate chemical for corrosion control. With the addition of orthophosphate at the Pequannock WTP, the orthophosphate residual concentration in these systems will be more consistent when purchasing water from Newark.
- The areas experiencing blending between the Pequannock and Wanaque Gradients will benefit from a more stable orthophosphate residual coming from both the Pequannock and Wanaque Gradients.

Each consecutive system will be notified of the treatment changes at Newark via a letter explaining the change and recommendations for monitoring and flushing prior to implementation and documentation of the notification will be provided to NJDEP. The systems will be notified 30 days in advance of the transition to zinc orthophosphate and a reminder will be provided at least five (5) days prior to the transition. The City will schedule a meeting with the consecutive systems mentioned above to discuss the project and procedures in detail.

8.9 Recommendations Summary

Table 8-2 summarizes the recommendations presented in this report for the Pequannock service area.

Table 8-2 – Summary of CCT Recommendations for Pequannock

Factor	Immediate CCT Recommendation	Longer Term CCT Recommendation	Additional Notes
Chemical	Zinc Orthophosphate	Zinc Orthophosphate	
Dosage	0.5 mg/L as PO ₄ increasing to passivation dose of 3.0 mg/L as PO ₄	Minimum 1.0 mg/L as PO ₄ (or as determined by pipe loop study)	Evaluate dosage in pipe loop study
Feed Location	Valley Road Rechlorination Station	Valley Road Rechlorination Station	
System pH	Stabilize pH to 7.3 to 7.4	Stabilize pH to optimal pH from pipe loop study	Evaluate optimal pH in pipe loop study
Sodium Silicate	Maintain current dose	Replace with a more cost-effective pH adjustment chemical	Evaluate any negative impacts from eliminating sodium silicate addition in pipe loop study
Demonstration Study	Conduct pipe loop study in parallel with implementation of immediate addition of zinc orthophosphate	Apply results of pipe loop study to long-term CCT plan	
Monitoring	Implement representative monitoring program, including sequential sampling	Continue monitoring program and sequential sampling until conditions are stabilized	
Public Health	Point-of-use filters and conduct public education program	CCT optimization and LSL Replacement Program	

Works Cited

American Water Works Research Foundation and DVGW-Technologiezentrum Wasser. (1996). *Internal Corrosion of Water Distribution Systems. 2nd Edition*. Denver, CO.

AWWA. (2017). *Internal Corrosion Control in Water Distribution Systems, AWWA M58* (Vol. 2nd Edition). AWWA.

Boyd, G., Dewis, K., Korshin, G., Reiber, S., Schock, M., Sandvig, A., & Giani, R. (2008). Effects of Changing Disinfectants on Lead and Copper Release. *American Water Works Association*, 75-87.

Burlingame, G. a. (2004). How to Mine Your Lead and Copper Data. *30*(6), p. 16.

DeSantis, M. (2017). Conversion of Lead Corrosion Scale Under Changing Redox Conditions. *AWWA Annual Conference and Exposition*. Philadelphia, PA: AWWA.

DeSantis, M., Schock, M., & Bennett-Stamper, C. (2012). Incorporation of Phosphate into Destablized PbO₂ Pipe Scales. *AWWA WQTC*. Toronto, Ontario.

Giammar, D. (2017). *Processes Controlling the Time for Orthophosphate to Achieve Effective Corrosion Control*. Water Research Foundation.

Giani, R., Keefer, W., & Donnelly, M. (2005). Studying the Effectiveness and Stability of Orthophosphate on Washington DC's Lead Service Line Scales. *AWWA WQTC*.

McNeill, L., & Edwards, M. (July 2002). Phosphate Inhibitor Use at US Utilities. *Journal AWWA*, 57-63.

Newark, C. o. (1994). *City of Newark Report on Corrosion Optimization Study*. Little Falls, NJ.

Nguyen, C., Stone, K., Clark, B., & Edwards, M. (2010). *Impacts of Chloride: Sulfate Mass Ratio (CSMR) Changes on Lead Leaching into Potable Water*. Denver, CO: Water Research Foundation; USEPA.

NSF/ANSI 42: Drinking Water Treatment Units - Aesthetic Effects. (n.d.). *NSF/ANSI 42*.

NSF/ANSI 53: Drinking Water Treatment Units - Health Effects. (n.d.). *NSF/ANSI 53*.

Reiber, S. e. (1991). A General Framework for Corrosion Control Based on Utility Experience. *US EPA Seminar Publication*. American Water Works Association Research Foundation.

Schock, M. R. (2001). Tetravalent Lead: A Hitherto Unrecognized Control of Tap Water Lead Contamination. *AWWA Water Quality Technology Conference*. Denver, CO.

Taylor, J., Dietz, J., Randall, A., Norris, C., Alshehri, A., Arevalo, J., . . . Shekhar, A. (2008). *Control fo Distribution System Water Quality Using Inhibitors*. Orlando, FL: AWWA Research Foundation, Tampa Bay Water.

Tesfai, F., Constatsant, P., & Reibier, S. (2006). Precipitate Formation in the Distribution System Following Addition of Orthophosphate. *AWWA WQTC*.

Thompson, J. L. (1997). Sodium Silicate Corrosion Inhibitors: Issues of Effectiveness and Mechanism. *Water Quality Technology Conference*. Denver, CO.

Triantafyllidou, S., Schock, M., DeSantis, M., & White, C. (2015). Low Contribution of PbO₂-Coated Lead Service Lines to Water Lead Contamination at the Tap. *Environmental Science & Technology*, 3746-3754.

US Environmental Protection Agency. (1997). *Guidance Manual for Selecting Lead and Copper Control Strategies*.

US Environmental Protection Agency. (2016). *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems*. Office of Water (4606M).

USEPA. (2016, March). *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems*.

Water Research Foundation. (2008). *Control of Distribution System Water Quality using Inhibitors*. Denver: Water Research Foundation.

Exhibit E



State of New Jersey

PHILIP D. MURPHY
GOVERNOR

DEPARTMENT OF ENVIRONMENTAL PROTECTION

CATHERINE R. McCABE
COMMISSIONER

SHEILA Y. OLIVER
LT. GOVERNOR

Mail Code 401-04Q
Division of Water Supply & Geoscience
Water System Operations Element
Bureau of Water System Engineering
401 E. State Street - P.O. Box 420
Trenton, New Jersey 08625-0420
Tel #: (609) 292-2957 - Fax #: (609) 633-1495
<https://www.nj.gov/dep/watersupply/>

April 25, 2019

Kareem Adeem, Acting Director
Newark Water Department
920 Broad Street, Room B31-F
Newark, NJ 07102

**RE: Newark Water Department - PWSID: NJ0714001
Pequannock Gradient Corrosion Control Treatment Recommendation Approval
(Letter No. LCR180001) and Issuance of the Temporary Treatment Approval
(WTA190001)**

Dear Mr. Adeem:

The Bureau of Water System Engineering (Bureau) is in receipt of the Corrosion Control Treatment (CCT) Recommendation for Newark Water Department's (Newark) Pequannock Gradient as identified in the *Pequannock WTP Corrosion Control Review and Recommendations – Final Report* (Report) dated March 15, 2019. The CCT Recommendation for the Pequannock Gradient is to add **zinc orthophosphate** as a corrosion control inhibitor into the piping network to reduce lead solubility in the distribution system and ensure that corrosion control is optimized pursuant to the Lead and Copper Rule. Pursuant to 40 C.F.R. 141.81(e)(4) and 141.82(d), the Department approves the corrosion control treatment recommendations in the Report and designates the use of zinc orthophosphate as the optimal corrosion control treatment for the Pequannock Gradient. The Department is also issuing the enclosed Temporary Treatment Approval with an expiration date of July 31, 2020 to allow Newark to start using the zinc orthophosphate. At least ninety (90) days prior to the expiration of the Temporary Treatment Approval, Newark shall submit a permit application in accordance with N.J.A.C. 7:10-11.1 et seq. or Newark may seek to either extend the Temporary Treatment Approval or apply for a new Temporary Treatment Approval if corrosion control treatment is found to not be optimized at that time.

In order to avoid algal blooms caused by increased phosphorous concentrations from the zinc orthophosphate, the Report proposed dosing of zinc orthophosphate downstream of Newark's open-air Cedar Grove Finished Water Reservoir at the Valley Road Rechlorination Station located in Montclair. Water dosed with zinc orthophosphate will be distributed to Newark's

Pequannock Gradient along with three of Newark's consecutive systems which include Belleville Water Department, Bloomfield Water Department and Nutley Township.

As identified in the Report, the Pequannock Township Water Department, which supplements its own ground water supplies with water from Newark's Pequannock Water Treatment Plant (WTP), will not be receiving the zinc orthophosphate inhibitor as the system's location is upstream of the Cedar Grove Finished Water Reservoir. Newark shall evaluate all users supplied by the Newark's Pequannock WTP upstream of the Cedar Grove Finished Water Reservoir to determine if any satellite orthophosphate feed systems will be necessary in addition to the Valley Road Rechlorination Station feed system. Within 15 days of the date of this letter, Newark shall provide a proposed schedule for conducting this evaluation.

The following table indicates Newark's Immediate and Long Term CCT Recommendations for the Pequannock Gradient as identified in the Report.

Summary of CCT Recommendations for Pequannock Gradient

Factor	Immediate CCT Recommendation	Longer Term CCT Recommendation	Additional Notes
Chemical	Zinc Orthophosphate	Zinc Orthophosphate	
Dosage	0.5 mg/L as PO ₄ increasing to passivation dose of 3.0 mg/L as PO ₄	Minimum 1.0 mg/L as PO ₄ (or as determined by pipe loop study)	Evaluate dosage in pipe loop study
Feed Location	Valley Road Rechlorination Station	Valley Road Rechlorination Station	
System pH	Stabilize pH to 7.3 to 7.4	Stabilize pH to optimal pH from pipe loop study	Evaluate optimal pH in pipe loop study
Sodium Silicate	Maintain current dose	Replace with a more cost-effective pH adjustment chemical	Evaluate any negative impacts from eliminating sodium silicate addition in pipe loop study
Demonstration Study	Conduct pipe loop study in parallel with implementation of immediate addition of zinc orthophosphate	Apply results of pipe loop study to long-term CCT plan	
Monitoring	Implement representative monitoring program, including sequential sampling and pipe scale analysis	Continue monitoring program and sequential sampling until conditions are stabilized	
Public Health	Point-of-use filters and conduct public education program	CCT optimization and LSL Replacement Program	

Based on the Bureau's review of the Report and its supporting documentation and analytical results, the Bureau approves the Report's recommendation to install the zinc orthophosphate chemical feed. All timeframes for completed tasks associated with the design, permitting, construction and placing the CCTR in service shall be in accordance with the Supplemental Compliance and Agreement Order (SCAO) NEA-180002 which was executed March 29, 2019. The Bureau reserves its right to modify its optimal corrosion control treatment designation under 40 C.F.R. 141.82(h).

Prior to and following the installation and operation of the zinc orthophosphate chemical feed at the Valley Road Rechlorination Station, the following conditions are required to be met:

1. On January 31, 2019, Newark submitted a request to the Bureau of Water System Engineering (Engineering) for a Temporary Treatment Approval to install a zinc orthophosphate feed system to reduce lead solubility in the distribution system from the treated water of the Cedar Grove Reservoir at the Valley Road Rechlorination Station. Newark shall install and operate the zinc orthophosphate feed system in accordance with the enclosed Temporary Treatment Approval.
2. At least ninety (90) days prior to the expiration of the Temporary Treatment Approval, Newark shall submit a permit application in accordance with N.J.A.C. 7:10-11.1 et seq. or Newark may seek to either extend the Temporary Treatment Approval or apply for a new Temporary Treatment Approval if corrosion control treatment is found to not be optimized at that time.
3. The zinc orthophosphate chemical feed could compromise the microbiological quality of the water supply. Since Newark is operating as a community water system, disinfection is required as the last treatment process as per N.J.A.C. 7:10-11.16. Because water from the Pequannock WTP is rechlorinated at the Valley Road Rechlorination Station after the zinc orthophosphate is dosed, the requirement to have disinfection as the last treatment process is met.
4. By April 28, 2019, in accordance with paragraph 27(I) of the executed SCAO, Newark shall submit for the Bureau's review and approval a proposed testing plan, which shall include sufficient sequential monitoring, pipe scale analyses, and WQP monitoring to determine whether designated optimal CCT has been achieved and WQPs have been stabilized. The testing plan must include, but not limited to, quantity of monitoring/pipe scale locations, frequency of sampling events, and the evaluation of number and location of WQP sites. Newark must evaluate its hydraulic gradients, pressure zones, population served of the Pequannock service area to determine if additional WQP sites are necessary. Newark shall refer to *EPA's Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems*.
5. By April 28, 2019, Newark is to submit a proposed pipe loop study protocol (referenced in the Final Pequannock CCT Report) to the Bureau for its approval.
6. Newark shall notify the Bureau in writing or via e-mail to the DEP Water Supply E-mail box at watersupply@dep.nj.gov at least one week prior to the commencement or

discontinuation of the use of zinc orthophosphate at the Valley Road Rechlorination Station.

7. Newark shall continue utilizing the existing silicate feed system at the Pequannock WTP until Newark fully implements an alternative CCT for the Pequannock Township Water Department.
8. Based upon *EPA's Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems*, the optimum pH for orthophosphate effectiveness is between 7.2 and 7.8. At a pH below 7.2, zinc orthophosphate will be slower to react and will not be as effective in reducing lead solubility. As identified in the Report, the current average pH at the Valley Road Rechlorination Station is approximately 7.1 at the point of entry (POE) into the distribution system. Newark is recommending that a higher, stabilized pH (7.3 – 7.4) be achieved leaving the Valley Road Rechlorination Station. The optimum pH range for Newark's Pequannock Gradient will be evaluated in the pipe loop study (referenced in Condition # 5 above) which is to be conducted simultaneously during the duration of the Temporary Treatment Approval.
9. If pH remains low at the Pequannock WTP, the Report proposes to install a satellite sodium hydroxide chemical feed system at the Valley Road Rechlorination Station to raise pH in the distribution system for zinc orthophosphate effectiveness. If Newark determines that such installation is necessary, a separate Temporary Treatment Approval or Permit to Construct and Operate would be required from the Bureau prior to its installation.
10. The addition of the zinc orthophosphate chemical feed will not change this system's treatment license classification from its current T4. The Licensed Operator shall submit Monthly Operator Reports, as required pursuant to N.J.A.C. 7:10A-1.12(d), to the Bureau of Safe Drinking Water no later than 10 days after the end of each month for which data is collected. The Monthly Operator Report shall include, but not be limited to, daily pH readings, daily dosage of zinc orthophosphate and daily treated water pumpage.
11. Newark shall submit a completed Corrosion Control Treatment Installation Completion Certification to the Bureau within thirty (30) days following completion of the zinc orthophosphate feed system installation.
12. Newark shall update and submit its WQP Sampling Plan to the Bureau within 30 days of the Bureau approving Newark's testing plan protocols under Condition # 4 above.
13. Newark evaluated additional source and finished water of the Pequannock WTP in relation to corrosion control, including additional water quality parameters such as manganese, chloride, sulfate, chlorine residual, total dissolved solids, and calcium as outlined on page 3-3 of the Report. Newark shall continue to monitor, evaluate and provide support that these parameters are not being impacted by the addition of zinc orthophosphate.

14. Newark will be required to continue Follow-up WQP monitoring throughout the duration of SCAO.

Please be advised that remedial measures undertaken to address a particular contaminant can adversely affect other analytes within the treatment train and/or distribution system. The United States Environmental Protection Agency has prepared a guidance document, "*Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules*", to assist water systems that need to address multiple analytes within their water system. This guidance manual can be accessed at <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=60000E2Q.txt>.

Since Newark is a large system and its existing treatment is not optimized, Newark will not be permitted to cease these approved CCT steps, regardless of whether Lead and Copper sampling demonstrates compliance with Action Levels, without written approval from the Bureau.

Your prompt attention to this matter is both necessary and appreciated. However, please also note that it is possible that further information and/or action may be necessary as both the Federal and State Safe Drinking Water programs continue to assess the implementation of the Federal Lead and Copper Rule to ensure the continued protection public health.

If you have questions regarding the above, please contact myself or Joe Mattle of my staff at (609) 292-2957 or at steven.pudney@dep.nj.gov or joseph.mattle@dep.nj.gov. When contacting the Department please reference PWSID No. NJ0714001 and Letter No. LCR180001.

Sincerely,



Steven Pudney CEng., MICE.
Section Chief - Engineering
Bureau of Water System Engineering

- c. Don Hirsch, Northern Bureau of Water Compliance and Enforcement
Rich Paull, Land Use and Water Compliance Enforcement
Tiffany M. Stewart, Esq., Newark Department of Water and Sewer Utilities
Jerry Notte, Licensed Operator (7 Winfield Court, Fairfield Twp., NJ 07004)
Sandra Kutzing, P.E., CDM Smith
Pat Gardner, Division of Water Supply and Geosciences
Linda Ofori, BWSE - Engineering
Kristin Hansen, BWSE – Water System Assistance
Joe Mattle, BWSE – Engineering
Michael Bleicher, BWSE – Water System Assistance
Matt Wilson, BSDW
Operator Certification, BSDW
Lead Team

Exhibit F

IN THE MATTER OF : **SUPPLEMENTAL COMPLIANCE**
CITY OF NEWARK - DEPARTMENT : **AGREEMENT & ORDER**
OF WATER AND SEWER UTILITIES :

NEA-180002

This Supplemental Compliance Agreement and Order (SCAO) is entered into pursuant to the authority vested in the Commissioner of the New Jersey Department of Environmental Protection ("Department") by N.J.S.A. 13:1D-1 et seq., the Safe Drinking Water Act (N.J.S.A. 58:12A-1 et seq.), specifically N.J.S.A. 58:12:A-9(c) and (i) and N.J.S.A. 58:12A-10, the Safe Drinking Water Act regulations (N.J.A.C. 7:10-1 et seq.), and the National Primary Drinking Water Regulations (40 CFR § 141.1 et seq.), and is duly delegated to the Chief of the Northern Bureau of Water Compliance and Enforcement pursuant to N.J.S.A. 13:1B-4.

FINDINGS

1. The City of Newark ("Newark") through its Department of Water and Sewer Utilities owns and operates a public community water system ("system"), as defined by N.J.A.C. 7:10-1.3, with Public Water System Identification number 0714001, located in the City of Newark, Essex County, New Jersey. The system is considered a large water system because it serves more than 50,000 people. See 40 C.F.R. § 141.2.
2. Newark is served by two distinct sources of water: the Pequannock Treatment Plant serves the western portion of the city ("Pequannock service area") and North Jersey District Water Supply Authority, also known as Wanaque North, serves the eastern portion ("Wanaque service area"). (See Exhibit A). To prevent the leaching of lead from pipes, the two sources have implemented different forms of corrosion control treatment ("CCT"). The Pequannock Treatment Plant uses silica and pH adjustments and North Jersey District Water Supply uses orthophosphate for CCT.
3. The New Jersey Safe Drinking Water regulations, specifically N.J.A.C. 7:10-5.1, -5.2(a)(9), incorporate by reference, the Lead and Copper Rule ("LCR") at 40 C.F.R. § 141.80 et seq.
4. On March 31, 2009, the Department and Newark executed an Administrative Consent Order, which required Newark to study options to bring its finished reservoir into compliance with 40 C.F.R. § 141.714.

Lead

5. On July 25, 2018, Newark and the Department entered into a Compliance Agreement and Order ("CAO") pertaining to Newark's obligations under the LCR. As discussed in the CAO, the entire Newark water system exceeded the lead action level in the first half of 2017. Although the LCR requires Newark to submit a CCT study and recommendation by October

31, 2019, Newark agreed to submit the study and recommendation by April 30, 2019 for the entire water system under the CAO. Newark also agreed to submit preliminary CCT studies prior to this deadline, including a final report on the Corrosion Control Optimization Desktop Analysis (“CCODA”) by October 15, 2018, an initial coupon study report by October 15, 2018 (to be followed with a final coupon study report by January 31, 2019), and an initial report on pipe scale testing by October 15, 2018 (to be followed with a final pipe scale testing report by January 31, 2019). This Supplemental Compliance Agreement and Order (“SCAO”) incorporates the Findings set forth in the CAO. As described below, Newark and the Department have had frequent communications regarding Newark’s ongoing CCT studies. On March 18, 2019, Newark requested a force majeure extension to certain deadlines related to the CCT studies under the CAO. Based on the findings set forth below, the Department hereby grants the extension and incorporates the new deadlines set forth in paragraph 33 below. Newark has been in substantial compliance with the CCT requirements specified by the Department in the CAO, as modified by this SCAO.

6. On October 1, 2018, the Department received a notification from the Environmental Protection Agency (“EPA”) regarding the results of sequential monitoring conducted at two residences in the Pequannock service area. The sequential monitoring involved taking ten samples in sequence from kitchen taps to determine the volume of water that would need to be flushed through a lead service line before the lead concentration would be reduced. Thereafter, on October 2, 2018, the Department received the EPA’s pipe scale analysis for the Pequannock service area and spoke with Newark’s consultants, CDM Smith, about the preliminary results of the CCODA for the Pequannock service area. The sequential monitoring and pipe scale analysis were part of the CCODA. The results of the sequential monitoring and the pipe scale analysis indicated that the usual recommendation to flush lead service lines to reduce exposure to lead may not be effective in the Pequannock service area. Newark informed the Department that it took immediate action to replace the lead service lines at the two homes where sequential monitoring was conducted. The pipe scale analysis conducted by EPA indicated that the silicate chemical used for corrosion control was no longer effective as a physical barrier in the lead service lines in the Pequannock service area.
7. On October 11, 2018, Newark submitted a draft CCT study and recommendation (Pequannock WTP Corrosion Control Review and Recommendations-Draft), dated October 10, 2018, to the Department. The report includes a CCT study for the Pequannock service area. The report indicates that corrosion control in this service area is no longer effective, as described in the previous paragraph.
8. On October 12, 2018, Newark started distributing free National Sanitation Foundation-certified (“NSF-certified”) water filters, which remove lead, to eligible residents in the Pequannock service area who have or may have lead service lines or lead plumbing elements, and any resident with a Newark-administered test that indicates a water lead level at 15 parts per billion or above.
9. Newark’s filter distribution program has provided filters door-to-door and at eight distribution centers throughout the city for pick-up. As of the execution of this SCAO, Newark has distributed approximately 35,000 filters under the program. On October 12, 2018, Newark

first informed residents about the availability of filters during a press conference and via public notice, and created a dedicated website (www.newarkleadsviceline.com) to provide residents with information about the program. Distribution began on October 12, 2018 at Newark City Hall and 239 Central Avenue. On October 13, 2018, three locations (329 Central Avenue, 916 South Orange Avenue, and 110 William Street) began distribution from 9:00am to 10:00pm. At these locations, education on filter installation and use was provided via video, written educational materials were provided to residents, and health and water department personnel were present to address questions. During the week of October 15, 2018, public notices were mailed to all residents and distributed to schools. Tele-townhall and Facebook Live events were held on October 15 and October 17, 2018. Between October 12 and December 14, 2018, Newark held six community meetings on the filter program. Each community meeting was preceded by a robo-call providing information on filter distribution, among other information. A city-wide public notice on the filter program was distributed on October 22, 2018. Newark has distributed information on the filter program to health clinics and family planning centers as well as the following hospitals: Beth Israel, St. Michael's, and University of Medicine and Dentistry of New Jersey. Newark has also utilized social media to inform residents about the filter program. Between October 12 and November 6, 2018, Newark posted 22 Facebook messages and 28 Twitter posts on the filter program. Newark issued its most recent press release on the filter program on March 21, 2019.

- A. The current filter and cartridge distribution center locations are: (i) Boylan Recreation Center – 916 South Orange Avenue; (ii) John F. Kennedy Recreation Center – 211 West Kinney Street; (iii) Vince Lombardi Center of Hope – 201 Bloomfield Avenue; (iv) St. Peter's Recreation Center – 378 Lyons Avenue; (v) Hayes Park West Recreation – 179 Boyd Street; (vi) Water & Sewer Facility – 239 Central Avenue; (vii) Department of Health & Community Wellness – 110 William Street; and (viii) City Hall – 920 Broad Street.

- i. Current pick-up hours at these locations are:

- 1. Recreations centers: Tuesday – Friday 11am to 8pm and Saturday 11am to 6pm;
 - 2. Health Department: Monday – Friday 8am to 4:30pm;
 - 3. Water & Sewer Facility: Monday – Sunday 8am to 8pm; and
 - 4. City Hall – Monday – Friday 9am to 5pm.

- 10. On October 26, 2018, the Department sent a letter to Newark responding to the draft CCT study and recommendation. (Exhibit B). The letter requires Newark to provide additional studies and information, including sequential sampling for the Wanaque service area and a recommendation regarding whether a pipe scale analysis is required for the Wanaque. The letter also directed Newark to submit additional studies and information for the Pequannock service area regarding: stabilizing the pH, addressing buffer capacity, the effect of CCT on the lime feed system, how operational issues affect fluctuating pH levels, addressing the pre-chlorination and pre-oxidation process, how Newark will achieve compliance with all other applicable safe drinking water regulations while conducting CCT, filter performance, the effect of iron and manganese in the distribution mains, maintaining adequate chlorine residual, and addressing consecutive system impacts.

11. On November 8, 2018 Newark submitted documentation in response to the October 26, 2018 letter, referenced in the previous paragraph. The Department reviewed the submission and responded to Newark with a follow-up letter dated November 30, 2018 requiring Newark to submit and/or address the following:
- A. Submission of a CCT report for the Wanaque Gradient by January 15, 2019. The CCT report was to include and/or address the following: sequential sampling and pipe scale analysis from “likely blending”, “potential blending” and “no blending” zones in the Wanaque Gradient. If results of the sampling and pipe scale analysis require additional optimization, a plan of action must be developed.
 - B. Effective transition from silicate to orthophosphate including whether special water quality parameter sampling will be conducted by Newark in their consecutive systems and what the optimum values would be;
 - C. Implementation of an effective distribution flushing program for Newark’s consecutive systems to ensure that the silicate is flushed out.
 - D. Determination of whether special lead/copper sampling should be conducted by Newark for their consecutive systems.
 - E. Acknowledgement that the silicate feed at the Pequannock Water Treatment Plant shall not be discontinued until Newark implements an alternative CCT for Pequannock Township Water Department.
 - F. Implementation of requirements outlined in the Department’s Source Water Changes and Treatment Modifications Guidance.
 - G. Acknowledgement that written notification be provided to Newark’s consecutive systems thirty days before and again five days before implementing the orthophosphate treatment.
 - H. A comprehensive flushing program for Newark’s distribution system prior to implementing a flushing program.
 - I. A final CCTR prior to the issuance of a treatment approval to add orthophosphate into the distribution system of the Pequannock Gradient at the Valley Road Rechlorination Station.
12. Newark initiated its CCT studies for the Wanaque Gradient. However, the federal government shutdown delayed work on the pipe scale analyses.¹ As such, on January 9, 2019, Newark requested an extension of the January 15, 2019 deadline to complete the Wanaque studies and committed to sending a draft CCT report within two weeks of receiving the pipe scale analysis results. On January 15, 2019, Newark submitted an additional letter stating that the sequential

¹ The federal government was shutdown for thirty-four days, from December 22, 2018 to January 25, 2019.

sampling data was undergoing quality assurance/quality control (“QA/QC”) review and that additional data was forthcoming. On January 25, 2019, Newark requested a three-day extension to February 1, 2019 to submit the initial Wanaque Gradient CCT Report due to laboratory testing issues associated with the sequential sampling. On February 1, 2019, Newark submitted a draft report entitled *Wanaque Gradient Corrosion Control Review and Recommendations* (“Draft Report”).

13. On February 13, 2019, the Department sent a letter in response to the Draft Report. (Exhibit E). The Department directed Newark to submit a schedule to conduct additional sequential monitoring and pipe scale analyses in the Wanaque Gradient and to provide a final report.
14. On March 6, 2019, Newark sent a letter to the Department proposing to perform the additional testing for the Wanaque Gradient and to submit a draft CCT report for the Wanaque Gradient by June 28, 2019. On March 18, 2019, Newark submitted a force majeure request under paragraph 45 of the CAO for an extension of paragraph 28.B of the CAO, which required Newark to submit the results of its CCT study and a final CCT recommendation by April 30, 2019. The Department hereby grants an extension of this deadline with regards to the Wanaque service area and incorporates the new deadline under paragraph 33 below.

HAA5 and TTHM

15. On October 31, 2018, revised November 5, 2018, the Department issued a Notice of Non-Compliance (“NONC”) (Exhibit C) to Newark for failing to comply with the Maximum Contaminant Level (“MCL”) for Total Haloacetic Acids (“HAA5”) under 40 C.F.R. 141.64(b). Specifically, the locational running annual average for HAA5 exceeded the MCL of 60 micrograms per liter (“ug/L”) during the July 1, 2018 to September 30, 2018 monitoring period at the following sampling locations by the following levels: SM11 (74 ug/L), SM12 (77 ug/L), SM19 (76 ug/L), SM5 (62 ug/L), STAGE1#204 (74 ug/L), STAGE1#203 (81 ug/L), STAGE1#202 (70 ug/L) and STAGE1#201 (73 ug/L). The individual monitoring results are as follows:

<u>Monitoring Period</u>	SM11 (ug/L)	SM12 (ug/L)	SM19 (ug/L)	SM5 (ug/L)
4th quarter 2017	55.0	47.9	46.8	35
1 st quarter 2018	34	33.0	36	31.8
2 nd quarter 2018	96.0	122.6	121.5	87.1
3 rd quarter 2018	109.2	103.1	100.7	95
LRAA	74	77	76	62

<u>Monitoring Period</u>	STAGE1 #204 (ug/L)	STAGE1 #202 (ug/L)	STAGE1 #203 (ug/L)	STAGE1 #201 (ug/L)
4th quarter 2017	39.4	45.8	55.5	41.8
1 st quarter 2018	24.6	26.5	30.6	22.9
2 nd quarter 2018	119.2	109.4	130.6	116
3 rd quarter 2018	112.0	98.0	106.5	113
LRAA	74	70	81	73

16. The NONC required Newark to conduct Tier 2 public notification of the HAA5 MCL violation by November 19, 2018, in accordance with 40 C.F.R. 141.201 et seq. and to submit a Remedial Measures Report Form (BWSE-40) and detail all proposed and completed remedial measures to the Department within 30 days of receiving the NONC. Newark was advised to consider how its actions may impact compliance with other contaminants by using EPA's guidance document, *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DPB Rules*. Newark submitted a Remedial Measures Report dated January 8, 2019, which the Department received on January 9, 2019. The Department reviewed the report and issued a response on March 1, 2019.

17. Pursuant to N.J.A.C. 7:10-5.7(a), Newark is required to take any action necessary to comply with the HAA5 MCL by October 18, 2019, including monitoring at the interconnections with its consecutive systems.

18. Newark exceeded the Operational Evaluation Level (OEL) under the Stage 2 Rule, 40 C.F.R. 141.626, for Trihalomethanes ("TTHM") at 10 locations during the third quarter of 2018. Data is provided in the table below.

Monitoring Period	STAGE1#203	STAGE1#201	SM12	STAGE1#204	STAGE1#202
1 st quarter 2018	27.2	20	31.7	26.3	32
2 nd quarter 2018	110	87.1	98.2	98.7	101.1
3 rd quarter 2018 *	93.5	124	103	107.5	106.2
3 rd quarter 2018 *	93.5	124	103	107.5	106.2
OEL LRAA (µg/L)	81.1	88.8	84	85	86.4

Monitoring Period	Site 4	SM5	SM11	SM19	SM7
1 st quarter 2018	39.8	32	30.5	36.1	47
2 nd quarter 2018	96.7	104	92.4	105.6	75.8
3 rd quarter 2018 *	98.1	104.7	111.5	108.8	102
3 rd quarter 2018 *	98.1	104.7	111.5	108.8	102
OEL LRAA (µg/L)	83.2	86.4	86.5	89.8	81.7

**The 3rd quarter results above have been calculated as a monitoring period average because duplicate samples were collected at each site during the 3rd quarter. Not listed here because the LRAA did not exceed, only one result was reported for SM17.*

19. Newark exceeded the OEL under the Stage 2 Rule for TTHM at 9 locations during the fourth quarter of 2018. Data is provided in the table below.

Monitoring Period	STAGE1#203 (University Hospital)	STAGE1#201 (Beth Israel)	SM12 (801 North 6 th Street)	STAGE1#204 (Essex County Park)	STAGE1#202 (Senior Center)
<i>2nd quarter 2018</i>	<i>110</i>	<i>87.1</i>	<i>98.2</i>	<i>98.7</i>	<i>101.1</i>
<i>3rd quarter 2018 *</i>	<i>93.5</i>	<i>124</i>	<i>103</i>	<i>107.5</i>	<i>106.2</i>
<i>4th quarter 2018</i>	<i>64.3</i>	<i>63.9</i>	<i>64.2</i>	<i>66.8</i>	<i>64.0</i>
<i>4th quarter 2018</i>	<i>64.3</i>	<i>63.9</i>	<i>64.2</i>	<i>66.8</i>	<i>64.0</i>
OEL LRAA (µg/L)	83.0	84.7	82.4	85.0	83.8

Monitoring Period	Site 4 (239 Central Ave)	SM5 (94 William St)	SM11 (521 Ivy Hill Plaza)	SM19 (311 South 10 th St.)
<i>2nd quarter 2018</i>	<i>96.7</i>	<i>104</i>	<i>92.4</i>	<i>105.6</i>
<i>3rd quarter 2018 *</i>	<i>98.1</i>	<i>104.7</i>	<i>111.5</i>	<i>108.8</i>
<i>4th quarter 2018</i>	<i>65.3</i>	<i>64.7</i>	<i>65.5</i>	<i>64.9</i>
<i>4th quarter 2018</i>	<i>65.3</i>	<i>64.7</i>	<i>65.5</i>	<i>64.9</i>
OEL LRAA (µg/L)	81.4	84.5	83.7	86.1

20. On January 9, 2019, the Department issued a NONC (Exhibit D) to Newark for failing to comply with the Maximum Contaminant Level (“MCL”) for Total Haloacetic Acids (“HAA5”) under 40 C.F.R. 141.64(b). Specifically, the locational running annual average for HAA5 exceeded the MCL of 60 micrograms per liter (“µg/L”) during the period 10/01/2018 to 12/31/2018 for the following sample point IDs: 4, SM11, SM12, SM19, SM5, STAGE1#204, STAGE1#203, STAGE1#202, and STAGE1#201. Specifically, the LRAAs for during the 4th quarter of 2018 exceeded the MCL of 60 micrograms per liter (µg/L) at these locations: 4 (62 µg/L), SM11 (76 µg/L), SM12 (80 µg/L), SM19 (78 µg/L), SM5 (68 µg/L), STAGE1#204 (81 µg/L), STAGE1#202 (74 µg/L), STAGE1#203 (82 µg/L), and STAGE1#201 (79 µg/L).

Reporting Period	4 (µg/L)	SM11 (µg/L)	SM12 (µg/L)	SM19 (µg/L)	SM5 (µg/L)
1 st quarter 2018	26.3	34	33.0	36	31.8
2 nd quarter 2018	109.4	96.0	122.6	121.5	87.1
3 rd quarter 2018	51	109.2	103.1	100.7	95
4 th quarter 2018	59.9	65.6	60.8	55.2	59.2
LRAA	62	76	80	78	68

Reporting Period	STAGE1 #204 (µg/L)	STAGE1 #202 (µg/L)	STAGE1 #203 (µg/L)	STAGE1 #201 (µg/L)
1st quarter 2018	24.6	26.5	30.6	22.9
2nd quarter 2018	119.2	109.4	130.6	116
3rd quarter 2018	112.0	98.0	106.5	113
4th quarter 2018	69	64	61.1	66
LRAA	81	74	82	79

21. The NONC required Newark to conduct Tier 2 public notification of the HAA5 MCL violation by February 3, 2019 in accordance with 40 C.F.R. 141.201 et seq. and to submit a Remedial Measures Report Form (BWSE-40) and detail all proposed and completed remedial measures to the Department within 30 days of receiving the NONC.
22. Newark conducted Tier 2 public notification by February 3, 2019 and submitted a Remedial Measures Report dated January 8, 2019, which the Department received on January 9, 2019 and conditionally approved on March 1, 2019.
23. Based on the facts set forth in these FINDINGS, the Department and Newark have agreed to enter into this SCAO to memorialize a schedule of actions Newark will take, including those actions which surpass what is required by the Lead and Copper rules, N.J.A.C. 7:10-5.1, -5.2(a)(9), -5.4(a) and 40 CFR 141.80 et seq. Newark has agreed to the entry of this SCAO and to be bound by its terms and conditions.

ORDER

NOW, THEREFORE, IT IS HEREBY ORDERED AND AGREED THAT:

A. ENFORCEMENT COMPLIANCE SCHEDULE

24. All provisions of the March 31, 2009 Administrative Consent Order and the July 25, 2018 CAO remain in full force and effect, and Newark shall continue to be bound by them, except as otherwise expressly set forth below.

Water Filter Distribution

25. By May 15, 2019, Newark shall provide or attempt to provide a free NSF-certified water filter to remove lead and a one-year supply of filter cartridges that are NSF-certified to remove lead to each qualified residence, as described in paragraph 27 below. Thereafter, replacement cartridges shall continue to be provided or attempted to be provided to all qualified residences so that each qualified residence has a functioning filter cartridge until corrosion control has been installed and reviewed by the Department and optimal water quality parameters (“WQPs”) have been designated by the Department. Newark shall distribute the water filters and filter cartridges at no cost to the qualified residences.

26. To remedy the initial backlog of water testing requests from residents, Newark has requested the services of Garden State Laboratories, Inc., Agra Environmental and Laboratory Services, and the North Jersey District Water Supply Commission, which are certified laboratories, to process the backlog of testing requests and coordinate with those certified labs to determine appropriate reporting procedures. Newark shall continue to retain the services of these labs or at least three other certified labs until corrosion control has been installed and reviewed by the Department and WQPs have been designated by the Department.
27. Newark shall provide or attempt to provide the NSF-certified water filter and a one-year supply of cartridges to every qualified residence, as described in this paragraph by May 15, 2019.
- A. “Residence” means any single-family residence or multi-family residence having a service line less than 3 inches in diameter.² “Qualified residences” are residences in the Pequannock service area: (i) that receive water through a lead service line; (ii) that receive water through a service line whose lead content is unknown; and (iii) that has or may have lead solder or plumbing. Qualified residences also include every residence whose tap tested by Newark Water Department has a result at or above 15 ppb for lead, regardless of whether the residence is located in the Pequannock or Wanaque service area or diameter of service line. Any service line found to contain lead, regardless of its diameter size, shall be considered a qualified residence.³
 - B. Unless a qualified residence picked up their filter and one-year supply of cartridges at a distribution center, Newark shall deliver or attempt to deliver the filter and cartridges to every qualified residence by May 15, 2019.
 - C. Newark shall be deemed to have attempted to deliver a filter and one-year supply of cartridges to qualified residences, if Newark (i) documents at least two attempts to deliver the filter and replacement cartridges and (ii) leaves a door hanger. Door hangers shall contain information on how to obtain a water filter. Newark will revise the door hangers to add updated information on how to obtain filter replacement cartridges. Going forward, Newark shall use the updated door hangers. After making the initial two attempts to deliver the filters and cartridges, Newark shall document its attempt to notify every qualified residence on how to obtain the filter and replacement cartridges at least once every six months until the filter program ends under paragraph I below.
 - D. Newark shall continue to make the filters and cartridges available at distribution centers until May 15, 2019. Newark shall ensure that at least one distribution center

² Based on discussions with Newark and review of U.S. EPA and industry guidance, the Department understands that service lines in Newark three inches or greater in diameter are unlikely to contain lead.

³ The October 10, 2018 CCT study titled Pequannock WTP Corrosion Control Review and Recommendations-Draft concluded that CCT in the Pequannock service area is no longer effective. As such, the normal recommendation under 40 C.F.R. 141.85(a)(iv)(A) to flush the tap before consuming the water is not currently an effective precaution for minimizing exposure to lead for customers served by a lead service line in the Pequannock service area. However, flushing is still an effective precaution for customers in this service area who are not served by a lead service line.

will be open to distribute filters and cartridges until the filter program ends under paragraph I below.

- E. After May 15, 2019, Newark shall provide or attempt to provide a filter within five (5) days of anyone requesting a filter based on lead testing of their tap water over 15 ppb in either the Pequannock or the Wanaque service areas, where the testing was conducted by Newark. This paragraph shall remain effective until the filter program ends under paragraph I below.
- F. Newark has represented that when initial filters were distributed, it did not yet have replacement cartridges for distribution. As such, Newark shall ensure that a one-year supply of filters is distributed to qualified residences who have already received filters, but did not yet receive replacement cartridges. Going forward all filters will be distributed or attempted to be distributed with a one-year supply of replacement cartridges.
- G. Newark shall notify residents who have received filters that they may receive a replacement cartridge upon reaching the end of the useful life of the cartridges supplied by Newark. Newark shall provide replacement cartridges for pickup at the Water & Sewer Facility (239 Central Avenue) and City Hall (920 Broad Street). Qualified residents who are disabled or elderly may request delivery of replacement cartridges. Newark shall provide a replacement cartridge to such residents within five (5) days of the request. This paragraph shall remain effective until the filter program ends under paragraph I below.
- H. Within one (1) month of executing this SCAO, Newark shall provide for scheduling of appointments (via telephone) for home visits to qualified residences requesting assistance with installation, use, or maintenance of filters or replacement cartridges. If an adult resident is not present or Newark is refused entry two (2) or more times for a scheduled home visit, Newark must leave written materials on installation, use, and maintenance of filters and replacement cartridges after each attempt, and may opt to decline future appointment requests from that residence.
- I. Newark shall submit for the Department's review and approval: (i) within 30 days of the execution of the SCAO a proposed testing plan, which shall include sufficient sequential monitoring, pipe scale analyses, and WQP monitoring to determine whether designated optimal CCT has been achieved and WQPs have been stabilized, and (ii) within 180 days of the execution of the SCAO, a protocol proposing technical criteria and guidelines for ending the filter program ("filter protocol"). The Department, in its discretion, may rescind and order Newark at any time to revise the filter protocol to account for new information, facts, circumstances, or expert opinion. Any revised filter protocol is subject to Department review and approval. The filter program described above shall continue until the designated optimal CCT has been installed and its efficacy is reviewed and deemed optimized through the Department's designation of optimal water quality parameters ("OWQPs") in accordance with 40 C.F.R. 141.81(e)(7). Newark may request permission from the Department to end the "Water Filter Distribution" program in this section prior to the Department's designation of OWQPs. Prior to requesting permission to end the Water Filter Distribution program, Newark should seek a determination from the Department whether revisions are necessary for the currently-approved filter protocol. The Department shall approve the end of "Water

Filter Distribution” program in this section once the approved filter protocol described above in (ii) or any Department-approved revised filter protocol is met.

- J. The approved testing plan referenced in paragraph I above shall be enforceable under this SCAO.
-
28. Newark shall document each residence that receives a filter and cartridges and provide the Department with weekly updates on the total number distributed. Newark shall provide a monthly report that documents each residence in a Microsoft Excel compatible spreadsheet: filter distribution by address; service area (Pequannock or Wanaque); addresses requesting a home visit for assistance with installation, use, or maintenance of a filter or cartridges; and, whether the filter was distributed due to the presence of lead service lines, lead plumbing/fixtures, unknown service line material, or testing over 15ppb.⁴ If a tested residence is part of the compliance sampling pool, Newark shall include the PBCU identification number. In addition, the spreadsheet will indicate whether the filter was provided at a distribution center or via delivery.
 29. Except for large residential buildings for which Newark already has documentation on the metallurgical constitution of the building’s service line, Newark shall inspect all large residential buildings in the Pequannock service area built prior to 1953 (according to Newark, lead service lines (“LSLs”) ceased being installed in Newark in 1953) to determine whether the building is served by a lead service line. Newark shall document the date, inspector and results of each inspection. Such inspections shall be completed within 60 days of the execution of the SCAO. Within 14 days of completing the inspections, Newark shall submit to the Department the documentation concerning the service line metallurgical constitution and inspections. If any of these buildings are found to have lead service lines, they shall be considered a qualified residence and Newark shall deliver a filter to each residence in the building within 30 days of the inspection as provided in paragraph 27 above.

Corrosion Control Treatment

30. Newark shall comply with any future Department request for additional information or studies to support the CCT recommendation and shall respond by the deadline set forth in the Department request. Such Department requests and any deadlines set forth therein, or deadline extensions granted by the Department, shall be considered incorporated into this SCAO and shall be enforceable against Newark under the enforcement provisions of this SCAO. Likewise, any schedule required and approved by the Department regarding CCT shall be considered incorporated by reference into this SCAO and shall be enforceable against Newark under the enforcement provisions of this SCAO.
-
- A. Within thirty days of the execution of this SCAO, Newark shall provide proof that it replaced the lead service lines at the homes where it conducted sequential monitoring as described above in paragraph 6.

⁴ These weekly and monthly filter distribution reports are separate and apart from the obligations required under paragraph 54.

31. On January 31, 2019, Newark submitted a temporary treatment approval request to the Department to install the CCT for the Pequannock service area. Newark shall fully install and operate under the temporary treatment approval within 60 days of the Department's issuance of the temporary treatment approval. Newark submitted the final CCT recommendation for the Pequannock service area on March 18, 2019.
32. Newark shall fully install and operate the CCT for the Pequannock service area within 12 months of the Department designating such treatment in accordance with the LCR.
33. Newark shall submit a draft CCT report and recommendation for the Wanaque service area by June 28, 2019. Newark shall submit the final CCT results and CCT recommendation for the Wanaque service area by October 31, 2019.
34. Newark shall fully install and operate the CCT for the Wanaque service area within 12 months of the Department designating such treatment in accordance with the LCR.
35. Pursuant to 40 C.F.R. § 141.81(e)(6), Newark shall complete follow-up sampling in accordance with 40 C.F.R. §§ 141.86(d)(2) and 141.87(c)) within 36 months after the Department designates CCT.
 - A. Newark agrees to expedite this deadline and will complete follow-up sampling within 24 months.
36. Pursuant to 40 C.F.R. § 141.81(e)(8), Newark shall operate its water system in compliance with the optimal WQPs once designated by the Department.
37. Newark is required to re-evaluate its CCT and submit a CCT recommendation to the Department for review and approval, as required by 40 C.F.R. § 141.90(a)(3) after it selects an alternative for the uncovered finished reservoir (see paragraph 48 of the CAO) and for any other source or treatment change.

Public Education/Public Notification

38. Under paragraph 38 of the CAO, Newark is required to conduct public education within 60 days after the end of each monitoring period in which a lead action level exceedance occurs. Newark must conduct the public education in accordance with 40 C.F.R. § 141.85, except that Newark shall not recommend flushing for customers in the Pequannock service area that have or may have a lead service line. Newark must provide draft public education to the Department for review and approval two weeks in advance of anticipated distribution.
39. Newark agrees to take the following steps beyond what is required by the LCR:
 - A. Within fourteen days of the execution of this SCAO, Newark shall submit a draft letter to the Department that contains the information in paragraph C below. Newark shall modify the letter in accordance with the comments provided by the

Department and send the letter to all water customers within fourteen (14) days of receiving the Department's comments.

- B. Newark shall continue to post on its website and social media information that is consistent with paragraph C below. Newark will also maintain video and written instructions on filter installation, use, and maintenance on its website.
- C. Newark shall provide the following information to its customers:
 - i. Newark is providing NSF-certified water filters to remove lead to its water customers, free of cost, to (a) any single-family residence in the Pequannock service area that receives or may receive water through a lead service line or that may have lead solder or plumbing, (b) any multi-family residence in the Pequannock service area with a water service line less than 3 inches in diameter and that receives or may receive water through a lead service line or that may have lead solder or plumbing, and (c) any residence whose tap tested by Newark Water Department has a result at or above 15 ppb for lead, regardless of whether the residence is located in the Pequannock or Wanaque service area;
 - ii. information regarding replacement timeframes for filter cartridges;
 - iii. information on how qualified residences may request an appointment for assistance with installation, use, and maintenance of filters or cartridges;
 - iv. the locations and hours of operation of locations that filters and replacement cartridges are being distributed;
 - v. a recommendation that customers in qualified residences should use filtered or bottled water for drinking and cooking;
 - vi. a recommendation that children under the age of 6 and pregnant individuals in qualified residences should use bottled water until a filter is installed;
 - vii. a recommendation that bottled water should be used in qualified residences to prepare infant formula until a filter is installed;
 - viii. an instruction that hot water should not be run through filters;
 - ix. an instruction that boiling water will not remove lead;
 - x. a recommendation, consistent with the NJ Department of Health guidance, that parents of children under the age of 18 have each child's blood lead levels tested;
 - xi. the normal recommendation to flush pipes before consuming water is not recommended in the Pequannock service area for residences that receive, or may receive, water from a lead service line. Flushing is recommended for residences in the Pequannock service area that do not have a lead service line and for all residences in the Wanaque service area, based on currently available data;
 - xii. customers may receive free water tap testing for lead. Newark shall provide the phone number to arrange for the testing;
 - xiii. customers may receive free blood-testing for lead for any child aged eighteen or under. Newark shall provide the locations for the blood-testing and the phone number to make an appointment;
 - xiv. residences with children whose blood tests are equal to or above 5 micrograms per deciliter (ug/dL) will be provided with nurse case management and an inspection of the home by the Newark Department of

Health and Community Wellness to determine if there are sources of lead within the home;

- xv. Newark shall provide a phone number for any questions concerning Newark's lead program, and sources for general information regarding lead safety; and
 - xvi. the information in paragraph 39.C. shall be provided to customers in English, Spanish, and Portuguese.
40. Newark shall ensure that in all public education undertaken pursuant to the LCR, information is provided relating to the current status of corrosion control until the filter program ends under paragraph 27(I) above. Clear and separate public education shall be provided to both service areas, Pequannock and Wanaque.

Lead and Copper Monitoring

41. Newark shall include the following statement in their sampling instructions for lead and copper monitoring: "The water sample shall not be taken from a faucet that has a point-of-use filter and must instead be taken from a kitchen or bathroom tap that does not have a filter."
42. Newark shall include a question on its chain-of-custody form regarding whether the sample was taken from a tap that has a point-of-use or point-of-entry filter designed to remove inorganic contaminants.
43. Newark shall submit draft sampling instructions and chain of custody form to the Department within two weeks of the effective date of this SCAO.
44. Any sample from a tap that has a point-of-use or point-of-entry filter designed to remove inorganic contaminants shall not count toward determining lead or copper 90th percentile levels under 40 C.F.R. § 141.80(c)(3) or toward Newark meeting the minimum monitoring requirements under § 141.86(c). If taken, those sample results must be reported to the Department using the Non-Compliance Lead and Copper Tap Monitoring Form (BWSE-16) within 10 days after receipt of the results. Newark shall document the reasons for any sample that it finds to be invalid.

Lead Service Line Replacement Program

45. In late March 2018, Newark applied for \$7,447,630 in Drinking Water State Revolving Funding through the Department to offset some of the cost of LSL replacements for property-owners. Since March 2018, the Department has certified three projects for Newark's Phase 1 LSL replacement program, which are estimated to cost a total of \$12,175,000. Since Newark has a lead action level exceedance and a population greater than 100,000, it is eligible for 90% principal forgiveness for the total loan amount with a cap of \$10 million per application, i.e. 90% of \$10 million. Newark may submit a loan application for additional money each year. However, principal forgiveness funds are only available to systems under the existing funding program until the LSL program funds are depleted. Newark shall submit to the Department by June 30, 2019 a funding strategy (that will be subject to funding availability and approval) for

the replacement of lead service lines in its system over eight years, at a cost to property owners of no more than \$1,000.00 per line as set forth in paragraphs 34 through 37 of the CAO.

Additional Monitoring Requirements

Consecutive Systems

46. Pursuant to the October 26, 2018 letter referenced in paragraph 10, above, Newark was required to evaluate the current and potential impacts of CCT on consecutive systems. On November 8, 2018 Newark provided a response identifying the anticipated impacts regarding the addition of proposed CCT to the Pequannock source of supply for Pequannock Water Department, Belleville Water Department, Bloomfield Water Department, City of Elizabeth (c/o New Jersey American Water – Liberty) and Nutley Township. For each Department designation of CCT pursuant to paragraphs 32 and 34 of this SCAO, Newark shall submit within 30 days of the Department designation a draft letter to the Department that describes the designated CCT measures and the schedule for its full installation and operation. Newark shall modify the letter in accordance with the comments provided by the Department and send the letter to all consecutive systems within seven days of receiving the Department's comments.
47. Newark shall sample for HAA5, TTHMs, and water quality parameters at the interconnection for all of its consecutive systems that receive water from the Pequannock service area on a quarterly basis beginning the second quarter of 2019, April 1, 2019-June 30, 2019. The results of the sampling shall be provided to the consecutive systems within one week of receiving the results.
48. Newark must obtain and evaluate water quality data results, including HAA5, TTHM, and water quality parameters, from the consecutive systems that purchase water from Newark as part of its remedial measures to address the HAA5 MCL violation and TTHM OEL.

HAA5

49. On February 2, 2019, Newark conducted public notification for the second HAA5 exceedance.
50. On February 19, 2019, Newark submitted a completed Public Notification Certification Form indicating that the public notification for the second HAA5 exceedance was completed.
51. In accordance with N.J.A.C. 7:10-5.7, Newark shall respond to all future Department correspondences pertaining to the Remedial Measures Report Form (BWSE-40) and all proposed or completed remedial measures as referenced in paragraphs 16 and 22.
52. Pursuant to the State Primary Drinking Water Regulations at NJAC 7:10-5.7, Newark is required to take any action necessary to bring the water into compliance with the HAA5 MCL

violation within one year after receipt of the results that demonstrate an exceedance that constitutes a violation. Because Newark received notice on October 18, 2018, Newark is required to come into compliance with the MCL no later than October 18, 2019. Remedial actions may include, but are not limited to, providing treatment to remove the levels detected, removing the contaminated source from service, and/or using an alternate source(s) of water supply, such as connecting to another public water system.

TTHM

53. Newark exceeded the Operational Evaluation Level (OEL) under the Stage 2 Rule for TTHM at 9 locations during the fourth quarter of 2018. On March 1 and 18, 2019, Newark submitted an Operational Evaluation for TTHM. The Department is currently reviewing the Operational Evaluation. Newark shall comply with any future requests for additional information regarding the Operational Evaluation.

B. PROGRESS REPORTS

54. In addition to the quarterly progress reports required under the CAO and the reporting requirements under paragraph 28 above, Newark shall also submit monthly progress reports by e-mail in accordance with this SCAO. The monthly reports shall include, but not be limited to, the following:
- A. identification of site and reference to this SCAO;
 - B. status of permitting and planning approvals and any work at the site and progress to date;
 - C. difficulties or problems encountered during reporting period and actions taken to rectify;
 - D. activities planned for the next reporting period;
 - E. required and actual completion date for each item required by this SCAO;
 - F. an explanation of any non-compliance with the compliance schedule; and
 - G. evaluation of all corrective measures implemented to date.

C. STIPULATED PENALTIES

55. Newark shall pay stipulated penalties to the Department, as set forth below, upon the Department's written demand, only for Newark's failure to comply with (i) paragraph 27 regarding sampling, but not paragraph 35.A, (ii) the HAA5 requirements in paragraph 51, and (iii) the TTHM requirements in paragraph 53, unless the Department has notified Newark in writing that a stipulated penalty will not be assessed pursuant to the force majeure provisions of this ACO.

Calendar Days After Due Date

Stipulated Penalties

1 st -7 th calendar days of failure to comply with the schedule	\$100 per calendar day
8 th -14 th calendar days of failure to comply with the schedule	\$200 per calendar day
15 th plus calendar days of failure to comply with the schedule	\$500 per calendar day

56. Within sixty (60) calendar days after Newark's receipt of a written demand from the Department for stipulated penalties, Newark shall submit payment by suitable financial instrument, made payable to "Treasurer, State of New Jersey" in the amount of the stipulated penalties demanded by the Department pursuant to paragraph 55 above. Payment shall be mailed with the bottom portion of the Penalty Invoice Form supplied with the written demand. Payment shall be made to the following address:

New Jersey Department of Treasury
Division of Revenue
P.O. Box 417
Trenton, New Jersey 08646-0417

57. If Newark fails to pay stipulated penalties pursuant to the preceding paragraphs, the Department may take action to collect same, including, but not limited to, instituting civil proceedings to collect such penalties pursuant to Rules Governing the Courts under R. 4:67 and R. 4:70, or assess civil administrative penalties for violations of this SCAO.

58. The payment of stipulated penalties does not alter Newark's responsibility to complete all requirements of this SCAO.

D. FORCE MAJEURE

59. If any event occurs which is beyond the control of Newark and which Newark believes will or may cause delay in the achievement of the compliance schedule provisions of this SCAO, Newark shall notify the Department in writing within seven (7) calendar days of becoming aware of the delay or anticipated delay, as appropriate. In the notification, Newark shall reference this paragraph, describe the anticipated length of the delay, the precise cause or causes of the delay, and any measures taken or to be taken to minimize the delay. Newark shall take all necessary action to prevent or minimize any such delay.

60. The Department may adjust the deadlines in the Enforcement Compliance Schedule of this SCAO for a period no longer than the delay if the Department finds that:

A. Newark has complied with the notice requirements of the preceding paragraph;

- B. any delay or anticipated delay has been or will be caused by fire, flood, riot, strike, or other circumstances beyond the control of Newark; and
 - C. Newark has taken all necessary actions to prevent or minimize the delay.
61. If the Department denies Newark's force majeure request, Newark may be subject to civil and/or administrative enforcement actions. The burden of proving that any delay is caused by circumstances beyond the control of Newark and the length of any such delay attributable to those circumstances shall rest with Newark. Increases in the cost or expenses incurred by Newark in fulfilling the requirements of this SCAO shall not be a basis for an extension of time. Delay in an interim requirement shall not automatically justify or excuse delay in the attainment of subsequent requirements. Contractor's breach shall not automatically constitute force majeure. No force majeure adjustments will be granted for failure to timely submit progress reports.

E. GENERAL PROVISIONS

62. Nothing contained in this SCAO restricts the ability of the Department to raise the above Findings in any other proceeding, specifically including, but not limited to, proceedings pursuant to N.J.S.A. 13:1E-126 et seq., (commonly referred to as A-901).
63. This SCAO settles and resolves only the issues related to this SCAO, and is not a settlement of any other action rising from those violations. Nothing in this SCAO shall resolve or preclude prosecution of criminal actions against Newark, if any.
64. This SCAO shall be binding on Newark, its respective agents, successors, assigns, and any trustee in bankruptcy or receiver appointed pursuant to a proceeding in law or equity. Additionally, this SCAO shall be binding on any Newark officials, employees, principals, directors, and officers to the extent that any such individual is a responsible corporate official within the meaning of N.J.S.A. 58:10A-31.
65. This SCAO shall be fully enforceable as a final Administrative Order in the New Jersey Superior Court upon the filing of a summary action for compliance pursuant to N.J.S.A. 58:12A-9(b), (c), (i), 58:12A-10, and N.J. Ct. R. 4:67-6.
66. Newark agrees not to contest the terms or conditions of this SCAO except that Newark may contest the Department's interpretation or application of such terms or conditions in any action brought by the Department to enforce this SCAO's provisions.
67. This SCAO shall not relieve Newark from obtaining and complying with all applicable federal, state and local permits as well as all applicable statutes, codes, rule, regulations and orders, including but not limited to the statutes and regulations cited herein.

68. No modification or waiver of this SCAO shall be valid except by written amendment duly executed by Newark and the Department or by the Department's written modification pursuant to the force majeure provisions herein.
69. Unless otherwise specifically provided herein, Newark shall submit all documents required by this SCAO, except penalty payments, to the Department electronically or by certified mail, return receipt requested or by hand delivery with an acknowledgment of receipt form for the Department's signature to:

Donald Hirsch, Chief
don.hirsch@dep.nj.gov
New Jersey Department of Environmental Protection
Northern Bureau of Water Compliance and Enforcement
7 Ridgedale Avenue
Cedar Knolls, New Jersey 07927

The date the Northern Bureau of Water Compliance and Enforcement receives the certified mail or executes the acknowledgment will be the date the Department uses to determine Newark's compliance with this SCAO.

70. Unless otherwise specifically provided herein, any communication made by the Department to Newark pursuant to this SCAO shall be sent via email with a return receipt requested or by hand delivery to:

Kareem Adeem, Acting Director of Water & Sewer
Adeemk@ci.newark.nj.us
920 Broad Street, Room B31F
Newark, New Jersey 07102


71. Newark shall not construe any unwritten or informal advice, guidance, suggestions, or comments by the Department, or by persons acting on behalf of the Department, as relieving Newark of its obligations under its permit(s), this SCAO, the New Jersey Safe Drinking Water regulations, and/or the New Jersey Safe Drinking Water Act.
72. In addition to the Department's statutory and regulatory rights to enter and inspect, Newark shall allow the Department and its authorized representatives access to the site at all times for the purpose of determining compliance with this SCAO.
73. Nothing in this SCAO shall preclude the Department from taking enforcement action against Newark for matters not set forth in the findings of this SCAO.
74. No obligations or penalties imposed by this SCAO are intended to constitute debt(s) which may be limited or discharged in a bankruptcy proceeding. All obligations and penalties are imposed pursuant to the police powers of the State of New Jersey for the enforcement of the law and the protection of public health, safety, welfare and the environment.

75. Newark shall give written notice of this SCAO to any successor in interest thirty (30) calendar days prior to transfer of ownership or control of the facility or facilities which are the subject of this SCAO and shall simultaneously notify the Department that such notice has been given. This requirement shall be in addition to any other statutory or regulatory requirements arising from the transfer of ownership or control of Newark's facility. In addition, the parties agree that any contract, lease, deed or any other agreement that Newark enters into to convey the property/facility that is the subject of this SCAO shall include a provision which states that the successor, assignee, tenant or purchaser has agreed to assume the obligations imposed by this SCAO.
76. The Department reserves all statutory and common law rights to require Newark to take additional action(s) if the Department determines that such actions are necessary to protect public health, safety, welfare and the environment. Nothing in this SCAO shall constitute a waiver of any statutory or common law right of the Department to require such additional measures should the Department determine that such measures are necessary.
77. Performance of the terms of this SCAO by Newark is not conditioned in any way on the receipt by Newark of any federal or state funds.
78. Newark shall perform all work required by this SCAO in accordance with prevailing professional standards.
79. This SCAO shall be governed and interpreted under the laws of the State of New Jersey.
80. If any provision of this SCAO is found invalid or unenforceable, the remainder of this SCAO shall not be affected thereby and each provision shall be valid and enforced to the fullest extent permitted by law. The Department does, however, retain the right to terminate the remainder of this SCAO if, after such finding, it determines that the remaining SCAO does not serve the purpose for which it was intended.
81. This SCAO represents the entire integrated agreement between the Department and Newark on the matters contained herein.
82. The Department reserves the right to unilaterally terminate this SCAO in the event Newark violates its terms and to take any additional enforcement action it deems necessary.
83. This SCAO shall terminate upon receipt by Newark of written notice from the Department that all the requirements of this SCAO have been satisfied. Termination of this SCAO shall not relieve Newark of any liabilities for unpaid penalties as previously demanded by the Department pursuant to the terms and conditions of this SCAO, nor shall it affect in any way the Department's rights and abilities to collect said unpaid penalties.
84. This SCAO shall become effective upon the execution hereof by all parties.

CITY OF NEWARK

DATE: 3/29/2019

BY:



Kareem Adeem
Acting Director of Water and Sewer Utilities
City of Newark

By this signature, I certify that I have full authority
to execute this document on behalf of Newark.

CITY OF NEWARK

DATE: 3/29/2019

BY:



~~Kenyatta K. Stewart~~ Eric S. Pennington
~~Corporation Counsel~~ Business Administrator
City of Newark

By this signature, I certify that I have full authority
to execute this document on behalf of Newark.

**DEPARTMENT OF ENVIRONMENTAL
PROTECTION**

DATE:

3/29/2019

BY:



Donald Hirsch, Chief
Northern Bureau of Water
Compliance and Enforcement

By this signature, I certify that I have full authority
to execute this document on behalf of the
Department.

Exhibit A

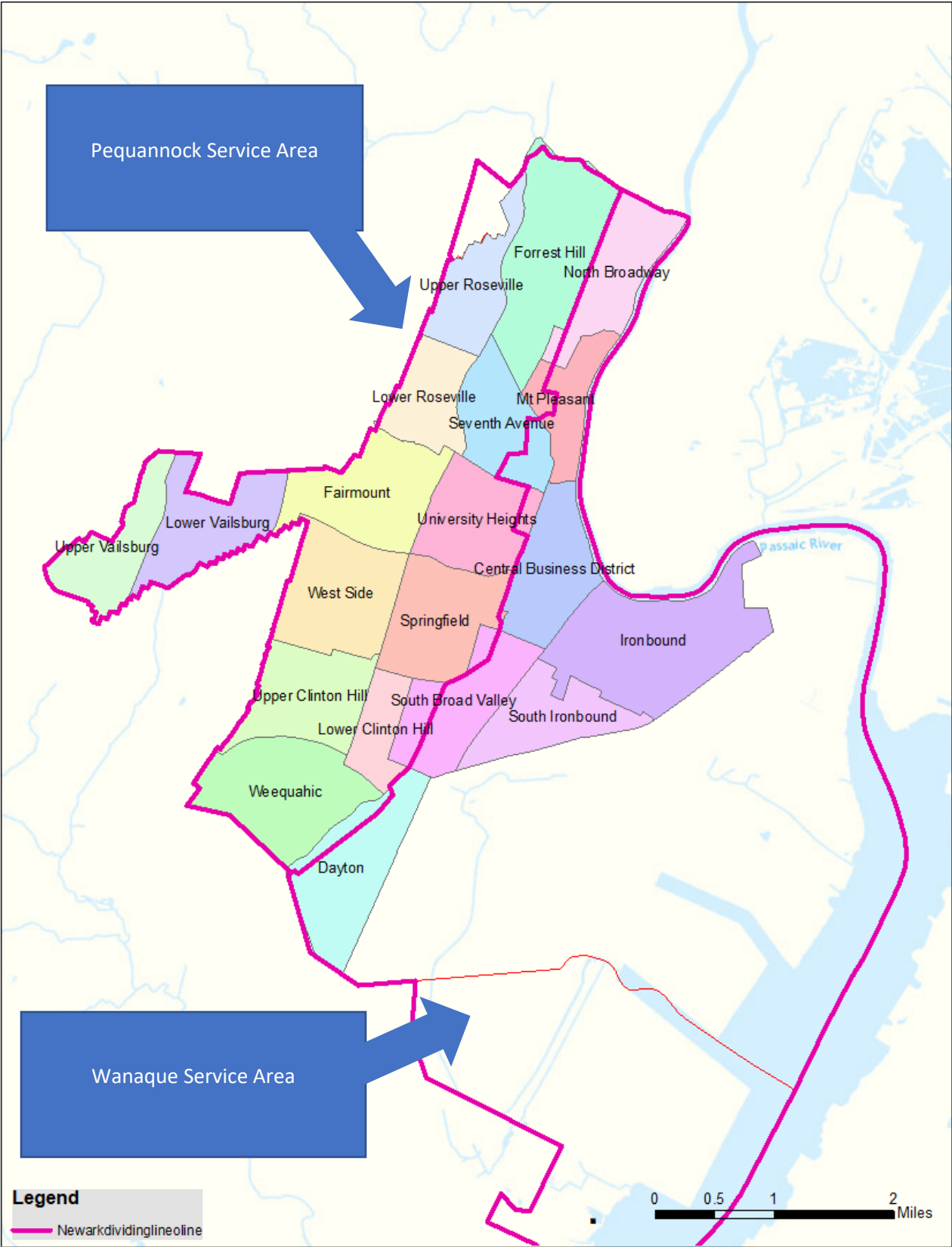


Exhibit B



State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Mail Code 401-04Q

Division of Water Supply & Geoscience

Water System Operations Element

Bureau of Water System Engineering

401 E. State Street - P.O. Box 420

Trenton, New Jersey 08625-0420

Tel #: (609) 292-2957 - Fax #: (609) 633-1495

<https://www.nj.gov/dep/watersupply/>

PHILIP D. MURPHY
GOVERNOR

SHEILA Y. OLIVER
LT. GOVERNOR

CATHERINE R. McCABE
COMMISSIONER

October 26, 2018

Andrea Hall-Adebowale
Newark Water Department
920 Broad St, Rm B31-F
Newark, NJ 07102

**RE: Newark Water Department - PWSID: NJ0714001
Pequannock WTP - Draft Corrosion Control Review and Recommendation
Letter No. LCR180001**

Dear Andrea Hall-Adebowale:

The Bureau of Water System Engineering (Bureau) is in receipt of the DRAFT Pequannock WTP Corrosion Control Review and Recommendations document dated October 10, 2018 ("Draft Report") for the City of Newark Lead and Copper Rule Compliance prepared by CDM Smith. The Draft Report was submitted as a draft of the Corrosion Control Treatment Study authorized by the Department on April 20, 2018, which required an assessment of the optimization of corrosion control treatment (CCT) for the City of Newark's (Newark's) water supply. The CCT study is required pursuant to 40 C.F.R. 141.81 and paragraph (28) of the July 25, 2018 Compliance Agreement and Order.

Based upon review of the documentation provided, the Bureau requires a written response to the following comments prior to submission of a Final Report:

Wanaque Gradient

1. The Draft Report only includes a corrosion control evaluation for Newark's Pequannock Gradient. A CCT review and recommendations report is required to be conducted for Newark's Wanaque Gradient. The evaluation of the Wanaque Gradient must include sequential sampling along with determining if a pipe scale study is required. In addition, Newark must evaluate whether elevated lead levels in the Wanaque Gradient can be attributed to the influence of Pequannock Gradient water leaking through division gates. A schedule for completion of this task shall be submitted.

Pequannock Gradient

2. The primary recommendation in the Draft Report for achieving optimized CCT is the addition of an orthophosphate chemical feed system. However, the Draft Report also shows that the pH in Pequannock Gradient is highly variable. Newark's pH must be stabilized and become reliable before implementing any form of optimal corrosion control as pH influences other corrosion control related parameters such as buffer capacity, alkalinity and Oxidation Reduction Potential (ORP).
 - The Draft Report does not evaluate or make any specific recommendation to address buffer capacity. Buffer capacity is a measure of the water's resistance to changes in pH, which depends on the water's alkalinity and Dissolved Inorganic Carbons (DIC) values. Newark's raw water alkalinity is low, and variable as indicated in the trend graphs. Low alkalinity is directly related to pH control stability, which impacts the water's buffering capacity. Therefore, Newark must demonstrate how it plans to address the pH variability or demonstrate how current alkalinity/DIC levels are acceptable.
 - If the upgraded lime feed system is being utilized to optimize pH, Newark must demonstrate that the lime feed system can accommodate the addition of phosphoric acid and/or orthophosphate for corrosion control.
 - Newark had advised that the fluctuating pH levels were due to operational issues as opposed to a buffering capacity issue. If the issues were or are based on operational issues, then Newark must explain those operational issues and how those operational issues will be resolved.
 - Pre-chlorination with chlorine gas lowers pH. Newark must address why this treatment step continues to be utilized or explain how and when the process will be discontinued and what, if any pre-oxidation process will be installed in its place.
3. While any adjustments are implemented to stabilize the pH in the Pequannock Gradient, simultaneous compliance must be maintained with all other applicable rules (e.g. EPA's Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules, Surface Water Treatment Rules).
4. Newark's existing filter performance must be evaluated.
5. Iron and manganese potentially located within Newark's distribution mains must be evaluated to determine their impact on Newark's CCT.
6. Adequate chlorine residual within the distribution system must be maintained.
 - Distribution disinfectant residual levels should be examined closely. Decreasing pH in a distribution system can lead to unstable and low disinfection residuals, as seen in the data provided thus far. Low disinfectant residual levels could lead to microbially-induced corrosion, which could be contributing to lead releases into the drinking water.

7. Consecutive system impacts

- Newark must evaluate current and potential impacts, including changes to the CCT inhibitor and pH adjustment, to the Pequannock Water Department which is located upstream of the proposed orthophosphate injection location.
- Address how any changes to the corrosion control process impacts Newark's remaining consecutive systems {Belleville Water Department, Bloomfield Water Department and City of Elizabeth (Liberty Water Company c/o NJ American Water)}.
- For the evaluation of the above consecutive systems, Newark shall refer to the Department's Source Water Changes and Treatment Modifications Guidance available at <https://www.state.nj.us/dep/watersupply/pdf/change-source-treatment-guidance.pdf>

Newark Water Department must address the above comments and provide a response to the Bureau within 14 days of the date of this letter.

If you have any questions regarding the above, please contact Steven Pudney or myself of the Bureau of Water System Engineering at (609) 292-2957 or via e-mail at Steven.Pudney@dep.nj.gov or Joseph.Mattle@dep.nj.gov. When contacting the Department please reference PWSID No. NJ0714001 and Letter No. LCR180001.

Sincerely,



Joseph J. Mattle, Supervisor
Bureau of Water System Engineering

- c. Northern Bureau of Water Compliance and Enforcement
Linda Ofori, BWSE – Engineering
Steven Pudney, BWSE – Engineering
Kristin Hansen, BWSE – Water System Assistance

Exhibit C



State of New Jersey

PHILIP D. MURPHY
GOVERNOR

SHEILA Y. OLIVER
LT. GOVERNOR

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Mail Code 401-04Q
Division of Water Supply & Geoscience
Water System Operations Element
Bureau of Safe Drinking Water
401 E. State Street - P.O. Box 420
Trenton, New Jersey 08625-0420
Tel #: (609) 292-5550 - Fax #: (609) 633-1495
<https://www.nj.gov/dep/watersupply/>

CATHERINE R. MCCABE
COMMISSIONER

November 5, 2018

CERTIFIED MAIL/RRR
7018 0680 0000 8443 2993

Andrea Hall-Adebowale
Newark Water Department
920 Broad St, Rm B31-F
Newark, NJ 07102

RE: Notice of Non-Compliance - Haloacetic acids MCL Exceeded
Newark Water Department
PWSID: NJ0714001
Sample Point ID: Distribution System
EA ID #: PEA180004 - 0714001

REVISED from 10/31/2018 Notice – Corrected Details in Corrective Actions #1 & #5

Dear Andrea Hall-Adebowale:

Enclosed for service upon you is a Notice of Non-Compliance issued by the Department.

Mail your response to this Notice of Non-Compliance to the Bureau of Water System Engineering at the letterhead address indicated above. If you need further assistance contact Michael Bleicher at (609) 292-2957 or Michael.Bleicher@dep.nj.gov. When contacting the BWSE, reference PWSID NJ0714001 and EA ID #: PEA180004 so that we can assist you more efficiently.

Sincerely,

A handwritten signature in cursive script that reads "Felicia Fieo for".

Felicia Fieo, Section Chief
Bureau of Safe Drinking Water

Enclosure

cc: Northern Bureau of Water Compliance and Enforcement (via e-mail)
Jerry J. Notte, Licensed Operator



State of New Jersey

PHILIP D. MURPHY
GOVERNOR

SHEILA Y. OLIVER
LT. GOVERNOR

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Mail Code 401-04Q
Division of Water Supply & Geoscience
Water System Operations Element
Bureau of Safe Drinking Water
401 E. State Street - P.O. Box 420
Trenton, New Jersey 08625-0420
Tel #: (609) 292-5550 - Fax #: (609) 633-1495
<http://www.nj.gov/dep/watersupply/>

CATHERINE R. MCCABE
COMMISSIONER

NOTICE OF NON-COMPLIANCE

EA ID #: PEA180004 - 0714001

Name: Newark Water Department
Location: Rt 23
Newfoundland, NJ 07480
Identifying #: NJ0714001

You are hereby Notified that a review of our records conducted on October 03, 2018, found that your facility was out of compliance with the regulations promulgated pursuant to the New Jersey Safe Drinking Water Act, NJSA* 58: 12A-1 et seq. This Notice of Non-Compliance has been recorded as part of the permanent enforcement history of Newark Water Department at the above location because your water system failed to comply with the following requirement:

Requirement: Comply with the Maximum Contaminant Level (MCL) for Total Haloacetic Acids as set forth in [40 CFR 141.64(b)].

Violation Details: LOCATIONAL RUNNING ANNUAL AVERAGE (LRAA) for TOTAL HALOACETIC ACIDS (HAA5) exceeded during the period 07/01/2018 to 09/30/2018 for the following sample point IDs: SM11, SM12, SM19, SM5, STAGE1#204, STAGE1#203, STAGE1#202, and STAGE1#201. Specifically, the LRAAs for during the 3rd quarter of 2018 exceeded the MCL of 60 micrograms per liter (µg/L) at these locations: SM11 (74 µg/L), SM12 (77 µg/L), SM19 (76 µg/L), SM5 (62 µg/L), STAGE1#204 (74 µg/L), STAGE1#203 (81 µg/L), STAGE1#202 (70 µg/L) and STAGE1#201 (73 µg/L) .

Reporting Period	SM11 (µg/L)	SM12 (µg/L)	SM19 (µg/L)	SM5 (µg/L)
4th quarter 2017	55.0	47.9	46.8	35
1 st quarter 2018	34	33.0	36	31.8
2 nd quarter 2018	96.0	122.6	121.5	87.1
3 rd quarter 2018	109.2	103.1	100.7	95
LRAA	74	77	76	62

* To locate citations: United States Code of Federal Regulations (CFR), see <http://www.gpoaccess.gov/cfr/index.html>. New Jersey Statutes Annotated (NJSA): Click on the STATUTES link at <http://www.njleg.state.nj.us/>. New Jersey Administrative Code (NJAC): http://www.nj.gov/dep/rules/rules/njac7_10.pdf

Reporting Period	STAGE1 #204 (µg/L)	STAGE1 #202 (µg/L)	STAGE1 #203 (µg/L)	STAGE1 #201 (µg/L)
4th quarter 2017	39.4	45.8	55.5	41.8
1 st quarter 2018	24.6	26.5	30.6	22.9
2 nd quarter 2018	119.2	109.4	130.6	116
3 rd quarter 2018	112.0	98.0	106.5	113
LRAA	74	70	81	73

In response to this Notice of Non-Compliance, the following corrective actions must be undertaken to achieve compliance:

1. A public water system exceeding the MCL for Haloacetic acids must report the violation to the Bureau of Safe Drinking Water (Bureau) within forty-eight (48) hours after becoming aware of the violation, in accordance with 40 CFR 141.31(b). *Your system complied with this reporting requirement on 10/18/2018.*
2. Tier 2 public notification requirements must be completed in accordance with 40 CFR 141.201 et seq. Public notification must be completed as soon as practical but no later than thirty (30) days after the system learns of the violation and must continue for the duration of the violation, but in no case for less than seven (7) days, even if the violation is resolved. *On October 19, 2018, Joseph duRocher of the Bureau forwarded a Tier 2 Public Notification template to Jerry Notte, Licensed Operator for Newark Water Department, which was subsequently reviewed and approved by Michael Bleicher of the Bureau of Water System Engineering. Public notification must be issued no later than November 19, 2018.*
3. Submit to the Bureau of Water System Engineering a representative copy(s) of each completed public notification that was distributed, posted, or otherwise made available to the persons served by your water system within ten (10) days of completing the public notification requirements. In addition, you must submit a completed Public Notification Certification Form (copy enclosed) for the specified violation in accordance with 40 CFR 141.31(d). The certification establishes that your water system has fully complied with the public notice content and delivery requirements pursuant to 40 CFR 141.201 et seq.
4. Submit a Remedial Measures Report Form (BWSE-40) and detail all proposed or completed remedial measures to the Bureau of Water System Engineering within thirty (30) calendar days of receipt of this letter. The report should include documentation (e.g., invoices, estimates, receipts) of the measures proposed or taken, and any corresponding analytical results that demonstrate the measures were effective. The Remedial Measures Report Form (BWSE-40) is available on the Bureau's website at <https://www.state.nj.us/dep/watersupply/pdf/bwse40.pdf>.
5. Pursuant to the State Primary Drinking Water Regulations at NJAC 7:10-5.7(a), you are required to take any action necessary to bring the water into compliance with the MCL within one year after receipt of the results that demonstrate an exceedance that constitutes a violation, i.e., **no later than October 18, 2019**. Remedial actions may include, but are not limited to, providing treatment to remove the levels detected, removing the contaminated source from service, demonstrating with analytical results that the current source of water no

longer exceeds the MCL (i.e. two (2) consecutive quarters where the Locational Running Annual Average is below the MCL at all HAA5 sample locations), and/or using an alternate source(s) of water supply, such as connecting to another public water system.

The Bureau has also reviewed recent Total Trihalomethane (TTHM) monitoring data and notes that the TTHM levels are also elevated in your water system at several locations. Although Newark Water Department has not incurred a TTHM MCL exceedance at this time, the TTHM MCL has been exceeded in the past and steps should be taken to address the elevated TTHM levels before the MCL is exceeded.

Please be advised that remedial measures undertaken to address a particular contaminant can adversely affect other analytes within the treatment train and/or distribution system. The United States Environmental Protection Agency has prepared a guidance document, "*Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules*", to assist water systems that need to address multiple analytes within their water system. This guidance manual can be accessed at <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=60000E2Q.txt>

This Notice of Non-Compliance does not constitute final agency action and may not be appealed or contested. The issuance of this Notice or your compliance therewith does not preclude the State of New Jersey or any of its agencies from initiating formal administrative and/or judicial enforcement action, including assessment of penalties, with respect to the items of non-compliance listed above or for any other violations. Violations of the above regulations are subject to penalties of up to \$25,000.00 per day/offense and in the event of formal administrative or enforcement action, you may appeal or contest such action and penalties.

Issued by: Felicia Fieo, Section Chief
Bureau of Safe Drinking Water

Signature: Jinda Doughty

Date: 11/5/18

BSD W-55
Address Updated
1/2014



Department of Environmental Protection – Division of Water Supply and Geoscience
Bureau of Safe Drinking Water
Mail Code 401-04Q - P.O. Box 420
Trenton, New Jersey 08625-0420
Tel # 609-292-5550 – Fax #609-292-1654

Office Use Only

Reviewed by:

Date:

Public Notification Certification Form – Tiers 1, 2 & 3

Requirements Pursuant to 40 CFR 141, Subpart Q and N.J.A.C. 7:10

****This form and a copy of your Notice to the Public must be submitted to the State within 10 days of notifying your customers. ****

PWSID#: 0714001

Water System Name: Newark Water Department

Violation #: 22943

Violation or Situation Date: _____

Individual Contaminant or Contaminant Group: Haloacetic acids

Monitoring Period: 07/01/2018 to 09/30/2018

Violation or Situation Type: (Check appropriate box) ☐ MCL ☐ Treatment Technique ☐ Water Main Break
☐ MRDL ☐ E. coli Positive Source Water Sample ☐ Monitoring and Reporting ☐ Other: _____

Violation or Situation Public Notification Tier: (Check appropriate box) ☐ Tier 1 ☐ Tier 2 ☐ Tier 3

Please check all that apply and provide information as indicated below:

1. ☐ Consulted with DEP within 24 hours (Tier 1) or 48 hours (Tiers 2 & 3) Date: _____
2. ☐ Distributed the notice by the following method(s), and on the following date(s) in accordance with 40 CFR 141.201 et seq:

- | | | |
|--------------------------|--|-------------|
| <input type="checkbox"/> | Reverse 911 | Date: _____ |
| <input type="checkbox"/> | Continuously Post | Date: _____ |
| <input type="checkbox"/> | Separate Mailing to Customers | Date: _____ |
| <input type="checkbox"/> | Hand Deliver Notice to Customers | Date: _____ |
| <input type="checkbox"/> | Publish Notice in Newspaper | Date: _____ |
| <input type="checkbox"/> | Release Notice to and Announced by Broadcast Media | Date: _____ |
| <input type="checkbox"/> | Post Notice on System Website | Date: _____ |
| <input type="checkbox"/> | Billing | Date: _____ |
| <input type="checkbox"/> | Annual Report (Consumer Confidence Report) | Date: _____ |
| <input type="checkbox"/> | Other: _____ | Date: _____ |

Note: Non-community water systems that serve a school, preschool or daycare must also hand deliver the notice to a parent or legal guardian of each child for Tier 1, 2 and 3 violations and situations. For more information reference EPA's Public Notification Handbook at: <http://www.epa.gov/safewater/publicnotification/compliancehelp.html>

3. ☐ **Content – 10 Required Elements Checklist:** 40 CFR 141 Subpart Q (Ensure all items are included in the notice)

- | | |
|--------------------------|--|
| <input type="checkbox"/> | Description of violation or situation including contaminant and contaminant levels as appropriate |
| <input type="checkbox"/> | Date violation or situation occurred. |
| <input type="checkbox"/> | Potential adverse health risks, using mandatory language provided in the rule. |
| <input type="checkbox"/> | Required language for Monitoring and Reporting Violations, provided in the rule |
| <input type="checkbox"/> | The population at risk, including sub-populations particularly vulnerable if exposed. |
| <input type="checkbox"/> | Whether alternate water supply should be used. |
| <input type="checkbox"/> | What action consumers should take, including when to seek medical help, if known. |
| <input type="checkbox"/> | What the system is doing to correct the violation or situation. |
| <input type="checkbox"/> | When the system expects to return to compliance or resolve the situation. |
| <input type="checkbox"/> | Contact information: Owner name, business address, and phone number of the water system owner, operator or designee that can provide additional information concerning the notice. |
| <input type="checkbox"/> | A statement encouraging recipients to distribute the notice to other persons served, using standard language from the rule. |

4. ☐ Attach a copy of the posted Public Notice(s) to this certification form.

The public water system named above hereby certifies that public notification has been provided to its consumers in accordance with all delivery, content, and format requirements specified in 40 CFR Part 141 and N.J.A.C 7:10.

Owner/Operator: _____
(circle one) (Signature) (Print Name) (Phone Number)

Date of Certification: _____ Operator License # (if applicable) _____

Exhibit D



State of New Jersey

PHILIP D. MURPHY
GOVERNOR

DEPARTMENT OF ENVIRONMENTAL PROTECTION

CATHERINE R. MCCABE
COMMISSIONER

SHEILA Y. OLIVER
LT. GOVERNOR

Mail Code 401-04Q
Division of Water Supply & Geoscience
Water System Operations Element
Bureau of Water System Engineering
401 E. State Street - P.O. Box 420
Trenton, New Jersey 08625-0420
Tel #: (609) 292-2957 - Fax #: (609) 633-1495
<https://www.nj.gov/dep/watersupply/>

January 9, 2019

CERTIFIED MAIL/RRR
7017 2400 0000 0140 3540

Kareem Adeem
Newark Water Department
920 Broad St, Rm B31-F
Newark, NJ 07102

RE: **Operational Evaluation Level Exceedance**
Newark Water Department
PWSID No.: 0714001

Dear Kareem Adeem:

The New Jersey Department of Environmental Protection, Bureau of Safe Drinking Water (Bureau) is in receipt of sample results collected under the Stage 2 Disinfectants and Disinfection By-Products Rule (Stage 2 Rule), specifically 40 CFR 141.620, and submitted on 01/03/2019. These results show that Newark Water Department exceeded the Operational Evaluation Level (OEL) for Trihalomethanes (TTHMs) at the nine (9) sites below for the 4th quarter 2018. Based upon a locational running annual average (LRAA) of three (3) quarters of monitoring data, the OEL was calculated to exceed the allowable limit of 80 µg/L as summarized below.

Monitoring Period	STAGE1#203 (University Hospital)	STAGE1#201 (Beth Israel)	SM12 (801 North 6 th Street)	STAGE1#204 (Essex County Park)	STAGE1#202 (Senior Center)
2 nd quarter 2018	110	87.1	98.2	98.7	101.1
3 rd quarter 2018 *	93.5	124	103	107.5	106.2
4 th quarter 2018	64.3	63.9	64.2	66.8	64.0
4 th quarter 2018	64.3	63.9	64.2	66.8	64.0
OEL LRAA (µg/L)	83.0	84.7	82.4	85.0	83.8

Monitoring Period	Site 4 (239 Central Ave)	SM5 (94 William St)	SM11 (521 Ivy Hill Plaza)	SM19 (311 South 10 th St.)
2 nd quarter 2018	96.7	104	92.4	105.6
3 rd quarter 2018 *	98.1	104.7	111.5	108.8
4 th quarter 2018	65.3	64.7	65.5	64.9
4 th quarter 2018	65.3	64.7	65.5	64.9
OEL LRAA (µg/L)	81.4	84.5	83.7	86.1

**The 3rd quarter 2018 results above were calculated as a monitoring period average since multiple samples were reported during the 3rd quarter.*

Any water system that exceeds the OEL under the Stage 2 Rule is required to complete an Operational Evaluation within 90 days of being notified of the exceedance (**Due: 04/03/2019**). Consecutive systems that purchase water should sample incoming water from their wholesale system(s) as part of this evaluation. Operational Evaluations will be reviewed by the Bureau of Water System Engineering and correspondence regarding the findings will be provided. It is to your benefit to address the OEL in a timely manner to avoid potential Maximum Contaminant Level (MCL) violations and the associated public notification requirements.

If you have any questions or wish to discuss the above matters further, please do not hesitate to contact Syed Rizvi of the Bureau of Water System Engineering at (609) 292-2957 or Syed-Imteaz.Rizvi@dep.nj.gov. When contacting the Bureau of Water System Engineering please reference the PWSID No. 0714001 and Letter No. WAM180002.

Sincerely,



Matthew Wilson, Environmental Specialist 3
Bureau of Safe Drinking Water

cc: Syed Rizvi, BWSE
Northern Bureau of Water Compliance and Enforcement

Exhibit E



State of New Jersey

Department of Environmental Protection
Mail Code 401-04Q

Division of Water Supply & Geoscience
Water System Operations Element
Bureau of Water System Engineering
401 E. State Street - P.O. Box 420
Trenton, New Jersey 08625-0420

Tel #: (609) 292-2957- Fax #: (609) 633-1495
<https://www.nj.gov/dep/watersupply/>

PHILIP D. MURPHY
Governor

SHEILA Y. OLIVER
Lt. Governor

CATHERINE R. McCABE
Commissioner

February 13, 2019

Kareem Adeem, Acting Director
Newark Water Department
920 Broad Street, Room B31-F
Newark, NJ 07102

**Re: Newark Water Department – PWSID: NJ0714001
Draft Report Wanaque Gradient Corrosion Control Treatment Recommendation –
Sequential Sampling
Letter No. LCR180001**

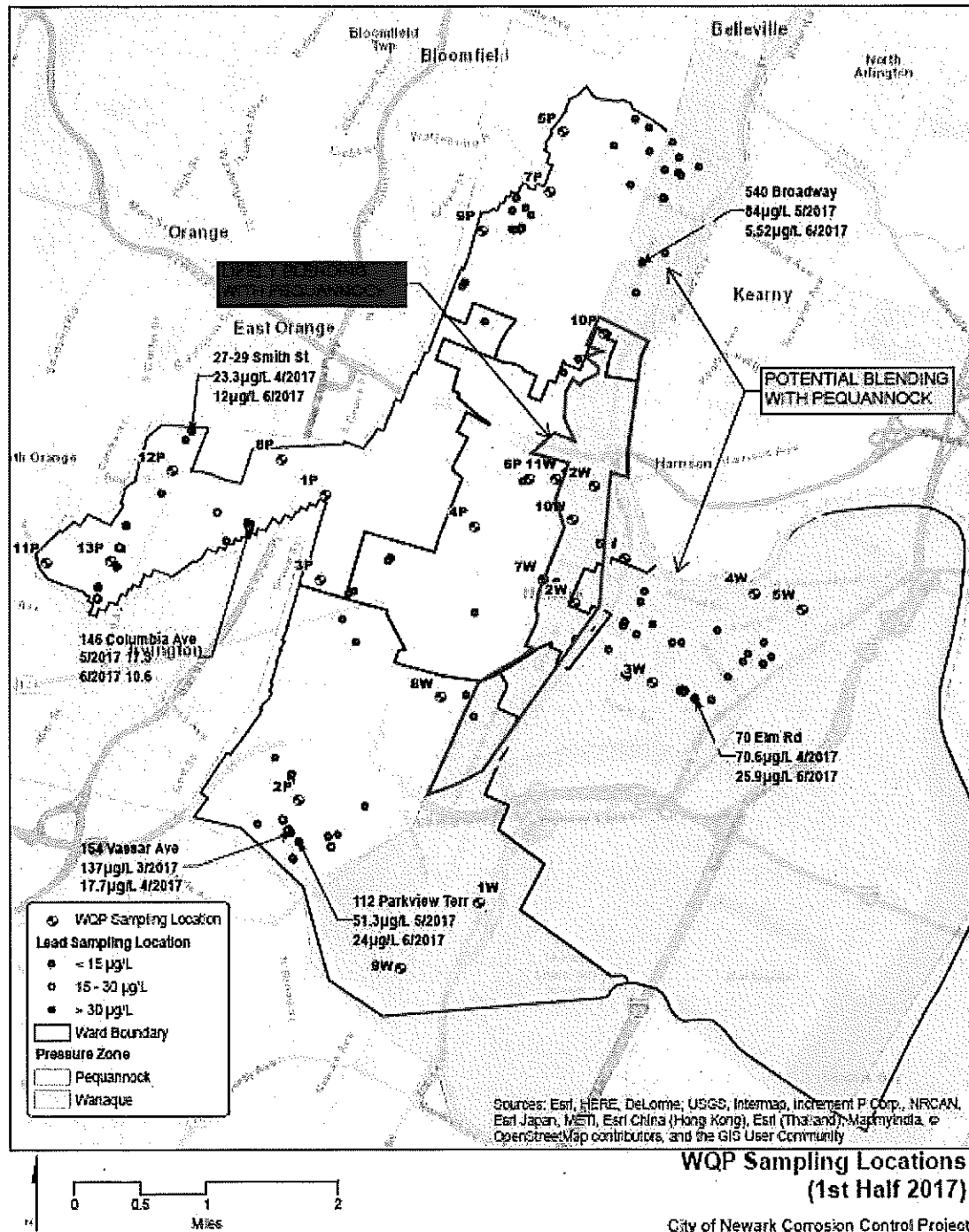
Dear Mr. Adeem:

As you are aware, due to the Newark Water Department's (Newark) lead action level exceedance (ALE), an assessment of the optimization of corrosion control treatment (CCT) is required pursuant to the Lead and Copper Rule, 40 C.F.R. 141.81. The Bureau of Water System Engineering (Bureau) authorized Newark's CCT study on April 20, 2018.

Newark originally submitted a draft Pequannock WTP Corrosion Control Review and Recommendations report, dated October 10, 2018. By letter, dated October 26, 2018, the Bureau provided comments on Newark's report and recommendations on the Pequannock gradient and noted that a CCT review and recommendation report was also required for the Wanaque gradient, which must include sequential sampling and pipe scale analyses, if appropriate. Further, Newark was required to evaluate whether elevated lead levels in the Wanaque gradient could be attributed to blending from the influence of the Pequannock gradient passing through division gates. A schedule for completion of the Wanaque study was due within fourteen (14) days of the letter.

Newark submitted a letter to the Bureau, dated November 8, 2018, stating that a CCT study for the Wanaque gradient would be submitted to the Bureau by January 15, 2019. It further noted that if the scale analysis was not complete by then, a supplemental memorandum would be provided upon completion of the analysis. To address the potential blending issue, Newark proposed to conduct sequential sampling and pipe scale analysis for homes with lead service lines ("LSL") in Wanaque gradient distribution system where Pequannock gradient water and the Wanaque gradient water were: (1) likely blending, (2) potentially blending, and (3) not blending.

By letter dated, November 30, 2018, the Bureau agreed with Newark's proposal to perform sequential sampling and pipe scale analyses in the identified zones, but found that while one sample location was sufficient in the "likely blending" and the "not blending" zones that Newark would need to sample one location from each of the two non-contiguous "potentially blending" zones as identified in Attachment 2 of Newark's November 8, 2018 correspondence to the Bureau (see figure below).



CDM
Smith

Attachment 2 - WQPs and Lead Sampling Results

Thereafter, Newark submitted a letter to the Bureau, dated January 9, 2019, noting that Newark had received word from the contractor performing the scale analysis with the United States Environmental Protection Agency (USEPA), Pegasus Technical Services, that they had received a stop-work notice as a result of the federal government shutdown. As such, Newark requested an extension of the January 15, 2019 deadline to complete the Wanaque Gradient Corrosion Control Treatment Recommendation (CCTR) and committed to sending a draft CCTR to the Bureau within two (2) weeks of receiving the pipe scale analysis results. Newark submitted an additional letter to the Bureau, dated January 15, 2019, noting that the sequential sampling data was undergoing QA/QC review and that additional data was forthcoming. Newark indicated that it was anticipated the sequential sampling data could be provided by January 29, 2019. The January 15, 2019 letter also noted that the pipe scale analysis continued to be delayed by the federal government shutdown and that a schedule for completion would be provided once USEPA's offices reopen. Subsequently, Newark submitted another letter to the Bureau, dated January 25, 2019, requesting a three-day extension from January 29, 2019 to February 1, 2019 to submit the initial Wanaque Gradient CCT Report due to laboratory testing inaccuracies associated with the sequential sampling.

The Bureau is now in receipt of the Newark's Draft Report entitled *Wanaque Gradient Corrosion Control Review and Recommendations*, dated February 1, 2019 (Draft Report). The Bureau recognizes the Draft Report was delayed, submitted in draft form, and is incomplete due to the QA/QC review of the sequential sampling data along with the delayed completion of pipe scale analyses at EPA's lab due to the Federal government shutdown as outlined in Newark's January 9 and January 15, 2019 letters.

Based upon a preliminary review of the Draft Report, the locations for testing and sampling do not fully comport with the Bureau's November 30, 2018 letter. Specifically, Newark has not provided sequential sampling data and pipe scale analysis locations within the Wanaque Gradient's "No Blending" Zone. Also, an additional pipe scale analysis was to be conducted in the second "Potentially Blending" Zone located within the Wanaque Gradient. The information required by the November 30, 2018 letter from the Bureau along with what was provided in the Draft Report are summarized in the following table. The asterisks identify outstanding information.

Wanaque Gradient - Blending with Pequannock Water	Sequential Sampling AND Pipe Scale Locations Requested by the Bureau (11/30/18 Letter)	Sequential Sampling Analysis Locations Conducted by Newark	Pipe Scale Analysis Locations Conducted by Newark
"Likely Blending" Zone	1	1	1
"Potentially Blending" (2 Zones)	2 (1 sample in each zone).	Total = 6 2 in the North Ward 4 in the East Ward	1*
"No Blending" Zone	1	0*	0*

To address the missing sequential sampling and pipe scale analyses, Newark shall provide a schedule and an outline for completion of these analyses to the Bureau within five (5) days from

the date of this letter. The Department will render a determination on Newark's extension request based on this submission.

The Bureau recognizes that Newark is waiting for EPA to conduct the pipe scale analyses on the two pipes that were submitted to EPA. Once the EPA provides its results to Newark or CDM Smith on these pipes and on the future pipes to be analyzed, Newark shall submit the results to the Bureau within two (2) days of receiving the results.

Please be advised that the Bureau is continuing to review the Draft Report and will provide additional responses as necessary. However, the Bureau will not have a final position on CCTR until Newark submits all of the requested sequential sampling and pipe scale analyses, as well as its recommendations, and such information is reviewed by the Bureau.

When contacting the Department please reference the PWSID No. NJ0714001 and Letter No. LCR180001.

Sincerely,

A handwritten signature in black ink, reading "Joe Mattle". The signature is written in a cursive, flowing style.

Joe Mattle, Supervisor
Bureau of Water System Engineering

cc: Don Hirsch, Northern Bureau of Water Compliance and Enforcement
Rich Paull, Land Use and Water Compliance and Enforcement
Tiffany M. Stewart, Esq., Newark Department of Water and Sewer Utilities
Sandra Kutzing, P.E., CDM Smith
Pat Gardner, Division of Water Supply and Geosciences
Linda Ofori, BWSE
Steve Pudney, BWSE – Engineering
Kristin Hansen, BWSE – Water System Assistance

NJEMS\sd_blank_letter_081511

Exhibit G

WANAQUE GRADIENT
CORROSION CONTROL
REVIEW

City of Newark
Lead and Copper Rule Compliance Study
Wanaque Gradient

Newark, NJ

City of Newark Department of
Water and Sewer Utilities

June 28, 2019



Table of Contents

Section 1 Introduction and Background.....	1-1
1.1 Current Corrosion Control Treatment (CCT).....	1-4
1.2 Lead and Copper Rule Compliance Sampling Results.....	1-5
1.3 Wanaque WQP and Test Locations.....	1-6
Section 2 Lead Frequency Distribution	2-1
2.1 Lead Frequency Distribution – Pequannock Service Area.....	2-1
2.2 Lead Frequency Distribution – Wanaque Service Area.....	2-4
2.3 Service Area Comparison	2-6
Section 3 Water Quality.....	3-1
3.1 Wanaque Gradient Point of Entry (POE) Water Quality Data	3-1
3.1.1 Belleville Data.....	3-1
3.2 Wanaque Gradient Distribution System Water Quality Data	3-2
3.2.1 Wanaque and Pequannock Mixing	3-3
3.3 Chloride-to-Sulfate Mass Ratio	3-7
Section 4 Sequential Sampling	4-1
4.1 Sequential Sampling Program Protocol	4-1
4.2 Results of Sequential Sampling in the Wanaque Gradient.....	4-2
4.2.1 South Ward – 95 Pennsylvania Avenue (Previously East Ward)	4-5
4.2.2 North Ward – 14 Hinsdale Place.....	4-8
4.2.3 East Ward – 26 ½ Gotthardt Street.....	4-12
4.2.4 East Ward – 285 Chestnut Street	4-14
4.2.5 East Ward – 64 Garrison Street.....	4-17
4.2.6 East Ward – 63 ½ Garrison Street.....	4-19
4.2.7 North Ward – 16 Hinsdale Place.....	4-21
4.2.8 South Ward – 85 Astor Street (Previously East Ward).....	4-24
4.2.9 South Ward – 12-14 Hanford Street	4-27
4.2.10 East Ward – 60 Gotthardt Street.....	4-30
4.3 Discussion	4-33
4.3.1 Differences Between LCR Compliance Sampling and Sequential Sampling	4-33
4.3.2 Samples with Soluble Lead Greater Than Total Load.....	4-35
4.3.3 Potential Causes of Lead Levels in Premise Plumbing.....	4-35
4.3.4 Comparison of Pequannock and Wanaque Sequential Sampling Results.....	4-36
Section 5 Scale Analysis	5-1
5.1 EPA Scale Analysis Testing and Results	5-1
5.2 EPA Elemental Analysis Testing and Results.....	5-5
5.2.1 95 Pennsylvania Avenue	5-5
5.2.2 14 Hinsdale Place	5-7
5.2.3 285 Chestnut Street	5-7
5.2.4 16 Hinsdale Place	5-7

• Table of Contents

5.2.5 85 Astor Street..... 5-7

5.3 Analysis of Results..... 5-8

5.3.1 Comparison of Sequential Sampling Results and Scale Analysis..... 5-8

Section 6 Recommendations..... 6-1

List of Figures

Figure 1-1 – Newark Water System Overview	1-2
Figure 1-2 – Lead Levels in the City of Newark (1992)	1-7
Figure 1-3 – Lead Levels in the City of Newark (1998)	1-8
Figure 1-4 – Lead Levels in the City of Newark (2002)	1-9
Figure 1-5 – Lead Levels in the City of Newark (2003)	1-10
Figure 1-6 – Lead Levels in the City of Newark (2006)	1-11
Figure 1-7 – Lead Levels in the City of Newark (2009)	1-12
Figure 1-8 – Lead Levels in the City of Newark (2012)	1-13
Figure 1-9 – Lead Levels in the City of Newark (2015)	1-14
Figure 1-10 – Lead Levels in the City of Newark (January – June 2017)	1-15
Figure 1-11 – Lead Levels in the City of Newark (July – December 2017)	1-16
Figure 1-12 – Lead Levels in the City of Newark (January – June 2018) – LCR Sampling Pool and Customer Requested Samples	1-17
Figure 1-13 – Lead Levels in the City of Newark (July – December 2018) – LCR Sampling Pool and Customer Requested Samples	1-18
Figure 1-14 – Newark’s WQP Sampling Locations	1-19
Figure 2-1 – Pequannock Service Area – Lead Sampling Data Percentage Frequency Distribution ..	2-2
Figure 2-2 – Wanaque Service Area – Lead Sampling Data Percentage Frequency Distribution	2-4
Figure 3-1 – Belleville Water Quality Data Trend	3-2
Figure 3-2 – Newark’s WQP Sampling Locations – Potential Influence from Pequannock on Wanaque Water Quality	3-6
Figure 4-1 – Sequential Sampling and Scale Analysis Locations in Wanaque	4-3
Figure 4-2 – 95 Pennsylvania Avenue Lead Profile – December 14, 2018	4-7
Figure 4-3 – 95 Pennsylvania Avenue Lead Profile – January 19, 2019	4-7
Figure 4-4 – 14 Hinsdale Place Lead Profile – December 14, 2018	4-10
Figure 4-5 – 14 Hinsdale Place Lead Profile – January 19, 2019	4-11
Figure 4-6 – 26 ½ Gotthardt Street Lead Profile – January 11, 2019	4-13
Figure 4-7 – 285 Chestnut Street Lead Profile – January 11, 2019	4-16
Figure 4-8 – 64 Garrison Street Lead Profile – January 11, 2019	4-18
Figure 4-9 – 63 ½ Garrison St. Lead Profile – January 16, 2019	4-21
Figure 4-10 – 16 Hinsdale Pl. Lead Profile – January 21, 2019	4-23
Figure 4-11 – 85 Astor Street Lead Profile – April 16, 2019	4-26
Figure 4-12 – 12-14 Hanford Street Lead Profile – April 16, 2019	4-29
Figure 4-13 – 60 Gotthardt Street Lead Profile – May 17, 2019	4-32
Figure 5-1 – Lead Scale Images for Pipe Extracted from 95 Pennsylvania Avenue	5-2
Figure 5-2 – Lead Scale Images for Pipe Extracted from 14 Hinsdale Place	5-2
Figure 5-3 – Lead Scale Images for Pipe Extracted from 285 Chestnut Street	5-2
Figure 5-4 – Lead Scale Images for Pipe Extracted from 16 Hinsdale Place	5-3

List of Tables

Table 2-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data	2-2
Table 2-2 – Pequannock Service Area Frequency Distribution Analysis	2-3
Table 2-3 – Summary of Statistical Parameters for Wanaque Lead Sampling Data	2-5
Table 2-4 – Wanaque Service Area Frequency Distribution Analysis	2-5
Table 3-1 – Water Quality Ranges for Wanaque POE and Raw Water Silica	3-1
Table 3-2 – Pequannock and Wanaque Gradient WQP Distribution System Water Quality	3-3
(July 2016 – December 2018)	3-3
Table 3-3 – Pequannock WQP Sampling Locations Summary (July 2016 – December 2018)	3-5
Table 3-4 – Wanaque WQP Sampling Locations Summary (July 2016 – December 2018; March –	
April 2019)	3-5
Table 4-1 – Water Quality Analysis at 95 Pennsylvania Avenue	4-6
Table 4-2 – 95 Pennsylvania Avenue Lead Results	4-6
Table 4-3 – Water Quality Analysis at 14 Hinsdale Place	4-9
Table 4-4 – 14 Hinsdale Place Lead Results	4-9
Table 4-5 – Water Quality Analysis at 26 ½ Gotthardt Street	4-12
Table 4-6 – 26 ½ Gotthardt Street Lead Results	4-13
Table 4-7 – Water Quality Analysis at 285 Chestnut Street	4-15
Table 4-8 – 285 Chestnut Street Lead Results	4-15
Table 4-9 – Water Quality Analysis at 64 Garrison Street	4-17
Table 4-10 – 64 Garrison Street Lead Results	4-17
Table 4-11 – Water Quality Analysis at 63 ½ Garrison St.	4-20
Table 4-12 – 63 ½ Garrison St. Lead Results	4-20
Table 4-13 – Water Quality Analysis at 16 Hinsdale Place	4-22
Table 4-14 – 16 Hinsdale Place Lead Results	4-22
Table 4-15 – Water Quality Analysis at 85 Astor Street	4-24
Table 4-16 – 85 Astor Street Lead Results	4-24
Table 4-17 – Flushed Water Quality Analysis at 85 Astor Street	4-25
Table 4-18 – Water Quality Analysis at 12-14 Hanford Street	4-27
Table 4-19 – 12-14 Hanford Street Lead Results	4-27
Table 4-20 – Flushed Water Quality Analysis at 12-14 Hanford Street	4-28
Table 4-21 – Water Quality Analysis at 60 Gotthardt Street	4-30
Table 4-22 – 60 Gotthardt Street Lead Results	4-30
Table 4-23 – Flushed Water Quality Analysis at 60 Gotthardt Street	4-31
Table 4-24 – Key Differences Between LCR Compliance Sampling	
and Sequential Sampling Protocols	4-33
Table 5-1 – General Characterization of Solid Phases in Pipe Deposits	5-4
Table 5-2 – Summary of Scale Composition Elemental Analysis Results	5-6
Table 5-3 – Comparison of Lead Sequential Sampling Data and EPA Scale Analysis Results	5-9

Appendices

Appendix A Wanaque Pipe Scale Analysis

This page intentionally left blank.

Section 1

Introduction and Background

The City of Newark (Newark) supplies approximately 80 million gallons per day (mgd) of water to a population of over 300,000 customers located in Newark, NJ and its surrounding communities. Newark's population of approximately 280,000 receives water through a large, complex distribution system that is managed by the City of Newark's Department of Water and Sewer Utilities (Department).

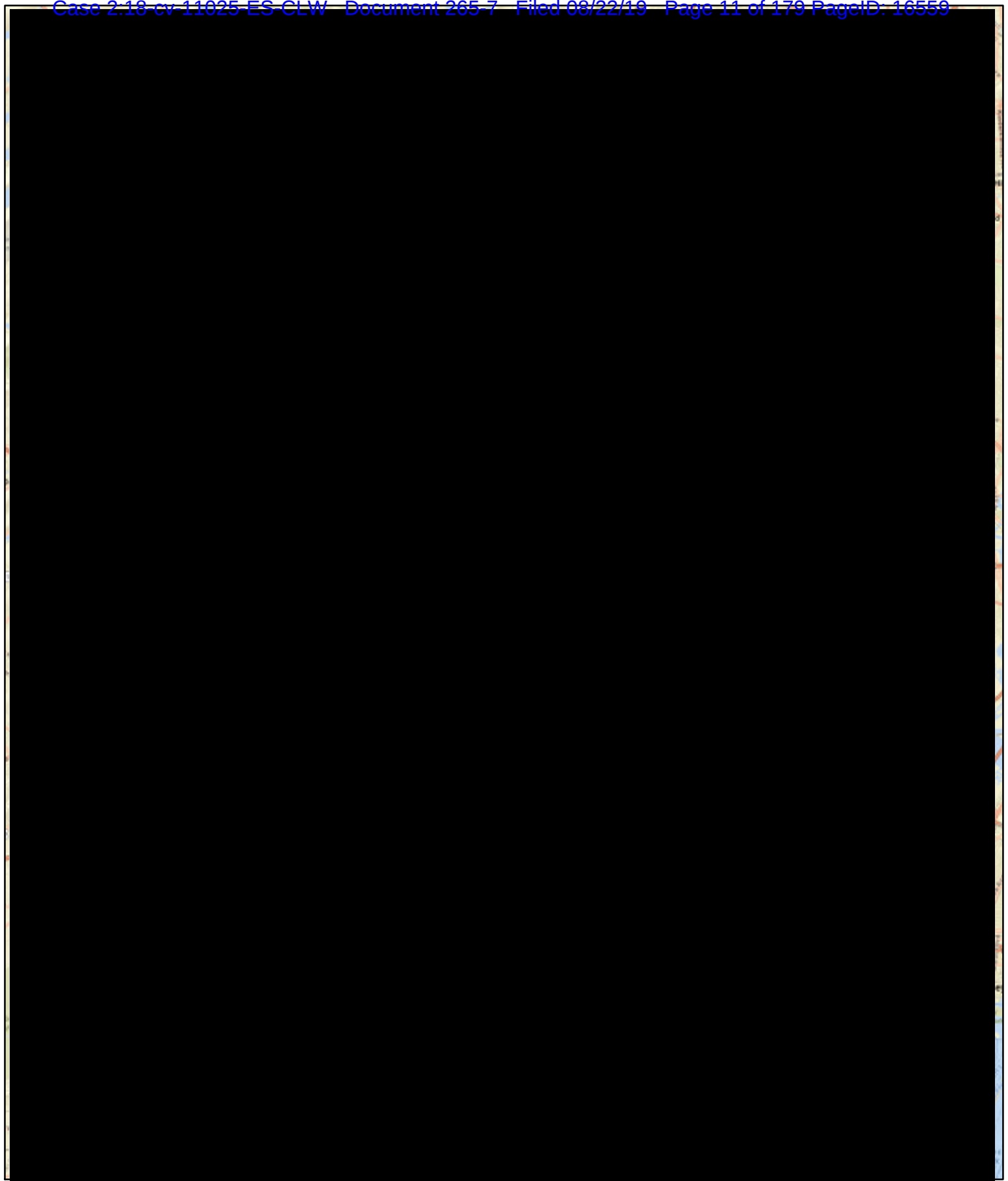
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

During the January to June 2017 Lead and Copper Rule (LCR) sampling round, Newark exceeded the Action Level (AL) for lead at the 90th percentile, based on sample results taken at 233 residences. On July 11, 2017, the New Jersey Department of Environmental Protection (NJDEP) sent a letter to Newark that outlined a series of required actions in response to the AL exceedance. Of the requirements, NJDEP required Newark to submit an Optimal Corrosion Control Treatment (OCCT) recommendation in accordance with 40 CFR 141.82(a) no later than six (6) months after the monitoring period when the AL was exceeded, or by December 31, 2017.



0 1.4 2.8 5.6 Miles

Newark Water System Overview

In response to NJDEP, Newark submitted an OCCT Memorandum on December 27, 2017. The 2017 OCCT Memorandum outlined the following recommended actions:

- Continue to collect the Water Quality Parameter data
- Completion of a corrosion control optimization desktop study
- Undertake a coupon study at several locations in the distribution system
- Conduct pipe loop testing

The 2017 OCCT Memorandum proposed the following Water Quality Parameters (WQPs) to be maintained for the Pequannock system:

- pH over 7.2
- Alkalinity over 30 mg/L
- Silica over 6.0 mg/L as SiO₂

Newark committed to increasing the sodium silicate dose to 12-15 mg/L from 8-12 mg/L, effective July 24, 2017.

The 2017 OCCT Memorandum also proposed the following WQPs to be maintained for the Wanaque Gradient in Newark's distribution system:

- pH over 7.2
- Alkalinity over 30 mg/L
- Orthophosphate above 0.4 mg/L as PO₄-P (or 1.2 mg/L as PO₄)

Optimal WQPs are typically established once corrosion control is optimized and after two consecutive 6-month follow-up WQP monitoring is performed showing compliance with the LCR. Since the 2017 OCCT Memorandum was issued, Newark has exceeded the lead AL in the second half of 2017 and both the first and second half of 2018. Therefore, Optimal WQPs have not yet been set by NJDEP.

In October 2018, the draft "Pequannock WTP Corrosion Control Review and Recommendations" prepared by CDM Smith provided the results of an evaluation of Newark's current corrosion control including an analysis of historic water quality and lead levels. The study indicated that an increase in lead levels since 2015 was occurring in the service area supplied by the Pequannock Gradient and not in the service area supplied by the Wanaque Gradient. Once this was determined, further analysis conducted for the October 2018 draft report focused on the Pequannock Gradient, including sequential sampling at customer homes and pipe scale analyses, to diagnose the cause of the increased lead levels.

Ultimately, it was concluded that the corrosion control treatment in the Pequannock system using sodium silicate was no longer effective for Newark's current water quality. As a result, protective scales, that had previously formed on lead service lines, were no longer providing corrosion

protection. It was also determined that flushing at the tap, a method generally accepted as a way for homeowners with lead service lines or lead-containing plumbing components to reduce exposure to lead in drinking water, was less effective for this particular situation. Furthermore, since the scale was unstable and could be easily disturbed, there was potential for releasing particulate lead into the water during flushing.

Since the Pequannock report was issued in October 2018, Newark constructed a zinc orthophosphate feed system at the Valley Road Rechlorination Station and commenced dosing orthophosphate on May 7, 2019. This system will benefit all residents served by Newark within the Pequannock Gradient. Zinc orthophosphate forms a protective barrier to reduce lead from leaching into the drinking water. In the interim while the zinc orthophosphate scale develops, Newark has established a program to distribute water filters and replacement cartridges to single family or multi-family homes in the Pequannock Gradient that have a lead service line or have interior plumbing comprised of copper piping with lead solder. Newark anticipates continued exceedances of the lead AL until the zinc orthophosphate can take effect, therefore, the filter distribution will continue until test results show lead levels decreasing in the system. In addition, Newark has increased its public education and awareness to notify residents of the lead levels found in older homes, particularly targeting those in higher risk categories.

On October 26, 2018, NJDEP provided comments on the October 2018 Pequannock draft report including requiring a more detailed corrosion control evaluation for the Wanaque Gradient, including sequential sampling, pipe scale analysis, and determining whether or not “elevated lead levels in the Wanaque Gradient can be attributed to the influence of Pequannock Gradient water leaking through division gates.” This report is a response to the first comment in NJDEP’s October 26, 2018 letter and focuses on the Wanaque water supply system to review the current corrosion control treatment and, if necessary, provide any recommendations for improvements.

A draft of this report was provided on February 2, 2019, while some of the testing and investigations were still ongoing. This June 2019 draft report includes updated information on the Wanaque system.

1.1 Current Corrosion Control Treatment (CCT)

The Wanaque water supply system, operated by the NJDWSC, has dosed zinc orthophosphate in Totowa, upstream of their Belleville Reservoir Complex, since the mid-1990s. When the LCR was established in 1991, both the Pequannock and Wanaque Gradients showed evidence of high lead levels when performing the initial requisite monitoring programs in 1992 and 1993. At that time, both systems commenced corrosion control studies and implemented corrosion control treatment (CCT) in the mid- to late-1990s.

NJDWSC typically targets the following water quality at the Belleville Reservoir Complex: pH of approximately 7.8 to 8.0, orthophosphate residual of approximately 1.8 to 2.2 mg/L as PO_4 , and a free chlorine residual of 0.80 to 1.0 mg/L. NJDWSC supplies several communities with drinking water either on a regular or emergency basis, including Wayne, Cedar Grove, Bayonne, Kearny, Montclair, Ringwood, communities served by Passaic Valley Water Commission (PVWC), and Newark. Some of these communities are supplied with water upstream of the zinc orthophosphate addition in Totowa, and add their own corrosion inhibitor, and some are

supplied with water downstream of the zinc orthophosphate addition. Of all the water suppliers that are provided water by NJDWSC, only PVWC and Newark have experienced non-compliance with the LCR within the last 10 years. Both PVWC and Newark have other sources of water with separate treatment in addition to the water obtained through NJDWSC.

Water quality within the Wanaque gradient of the Newark distribution system supplied by NJDWSC is discussed in Section 3.

1.2 Lead and Copper Rule Compliance Sampling Results

As noted above, due to consecutive rounds of lead AL exceedances in 1992 (90th percentile above the AL of 15 µg/L), both the Pequannock and Wanaque systems implemented CCT in the 1990s. After 1992, LCR compliance sampling was performed in 1998, 2002, 2003, 2006, 2009, 2012, 2015, 2017 and 2018 at residences throughout the City.

Maps showing the locations and lead concentration ranges for all compliance sampling events, including the initial sampling in 1992 leading to implementation of CCT, are provided in **Figures 1-2 through 1-13**. As shown in the figures, Newark experienced a period with very low lead concentrations at compliance sampling pool locations between 1998 and 2012. During this period, the compliance sampling locations varied by year and were not consistently representative of both the Pequannock and Wanaque supplies. For example, in 2002 and 2009, only homes receiving Wanaque water were sampled. In 1998 and 2006, only homes receiving Pequannock water were sampled. In 2015, slightly elevated lead concentrations were found, but they were still below the AL. Due to the significant increase in customer requested samples in 2018 (a total of 448 tested samples), the January to June 2018 and July to December 2018 graphs, **Figure 1-12** and **Figure 1-13** respectively, show both the results from the LCR compliance samples with verified pipe materials and the results from the customer requested samples that have not been verified and are not included in the 90th percentile calculation for LCR compliance. The LCR samples are identified as circles while the customer requested samples are identified as squares. Approximately 30 of the customer-requested samples were listed under a different address than their account address. The locations are still being determined and will be added to the map for the final report.

Lead levels exceeded the AL during the first and second half of 2017, as well as the first and second half of 2018. The AL was also exceeded in the last three sampling rounds in Bloomfield, one of Newark's consecutive systems, which receives a large percentage of its supply from Newark's Pequannock WTP. As corrosion control chemistry transitions are a slow process, it cannot be determined exactly when the lead levels started to increase. To monitor the transition of lead levels, the acceptable practice is to maintain routine monitoring of the water quality parameters as well as continue tap sampling under the LCR. Newark is in compliance with the LCR by performing all required monitoring and actions triggered by a lead AL exceedance.

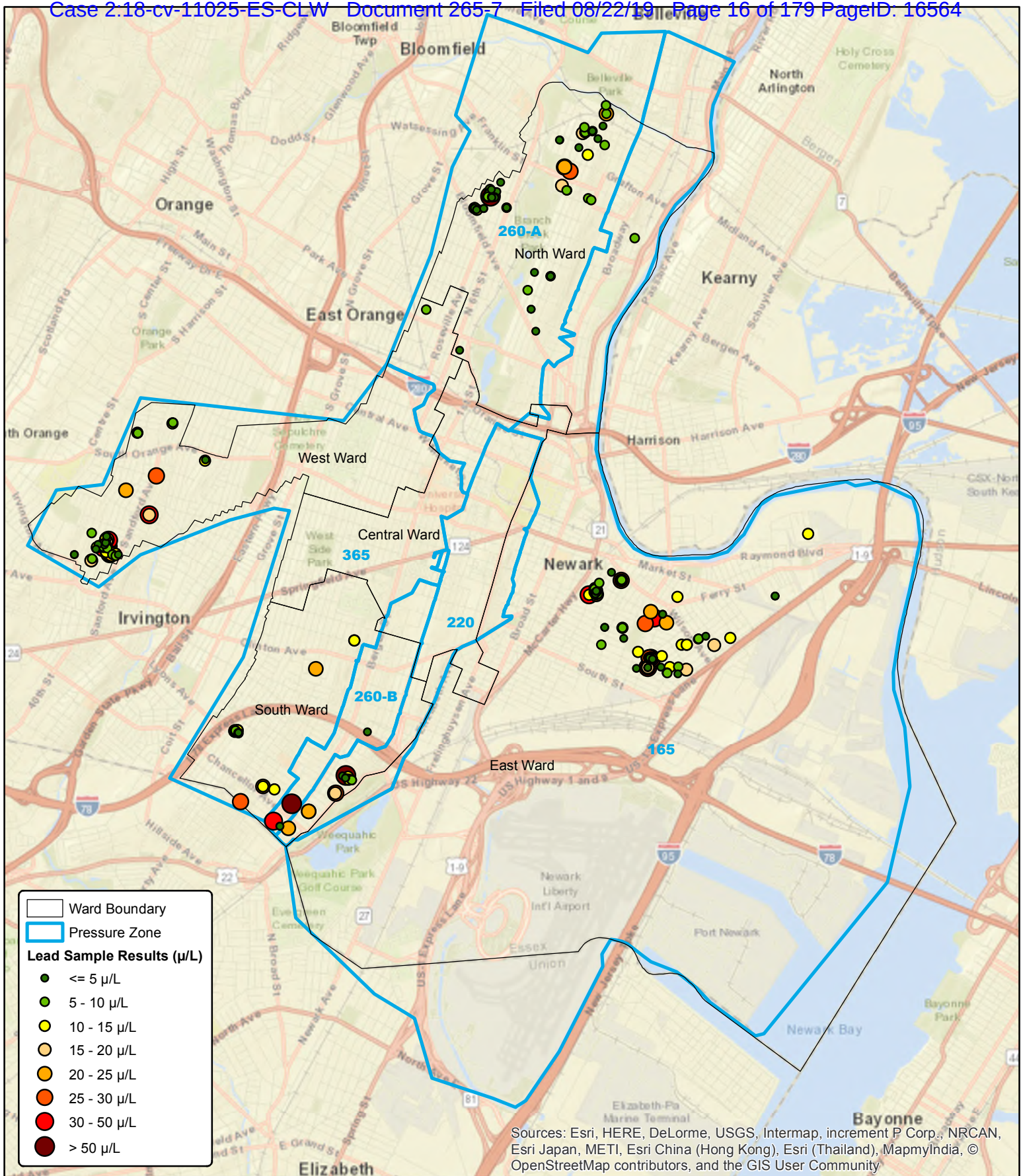
The LCR AL for copper is 1.3 mg/L at the 90th percentile value. Newark has not experienced high copper levels in their system based on the data analyzed other than one sample in the sequential sampling discussed in Section 4. Optimization of treatment for copper, therefore, is not addressed in this report.

1.3 Wanaque WQP and Test Locations

Water Quality Parameters (WQPs) are monitored at sample locations throughout a distribution system and are used to regularly monitor conditions pertaining to corrosion control. The sample locations and WQPs are typically established by the water utility and approved by NJDEP. Optimal targets are set once a utility is in compliance with the LCR. Newark proposed target WQPs as stated earlier in this Section and has been monitoring their WQPs since July 2016 on a bi-weekly basis. The monitoring locations for Newark's current WQPs are shown in **Figure 1-14**. According to the list, there are 13 WQP sampling sites in the Pequannock service area (labeled with "P") and 12 WQP sampling sites in the Wanaque service area (labeled with "W"). However, based on a recent review of the WQP locations, some updates have been proposed and are in the process of being finalized with the NJDEP. Based on the review, it appears that the following WQP sampling sites will need to be updated:

- 2W – Labeled as Wanaque but appears to be located in the Pequannock service area
- 8W – Labeled as Wanaque but appears to be located in the Pequannock service area
- 11W – Labeled as Wanaque but appears to be located in the Pequannock service area
- 10P – Labeled as Pequannock but appears to be located in the Wanaque service area

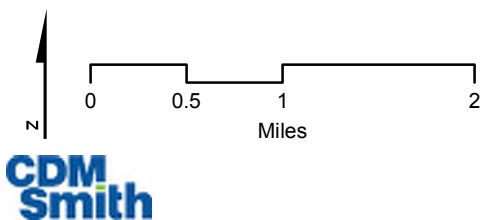
Therefore, these WQPs were evaluated based on the updated water sources for the water quality evaluations presented in Section 3.

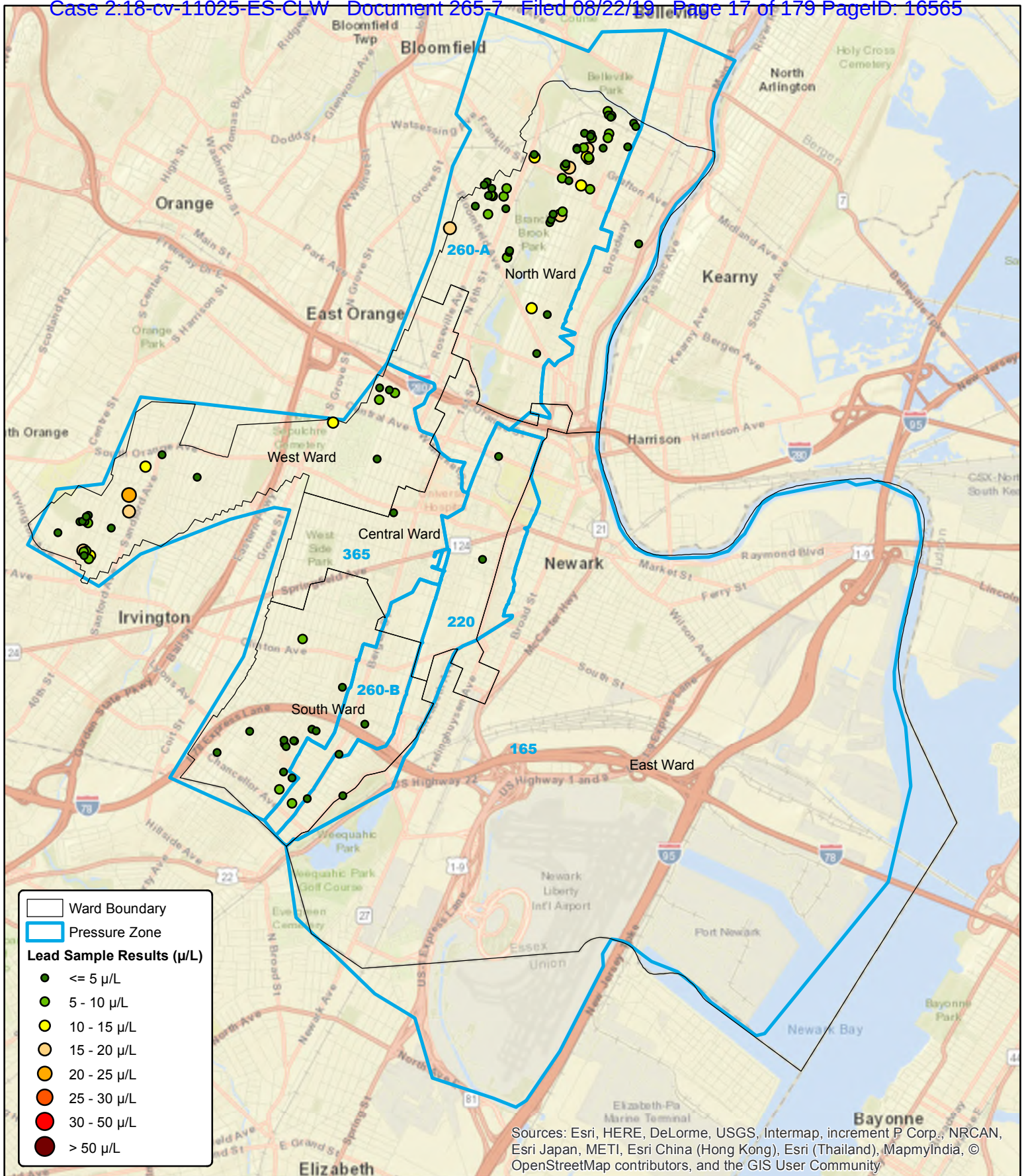


Lead Level in the City of Newark

Data Collected: 1992

Figure 1-2





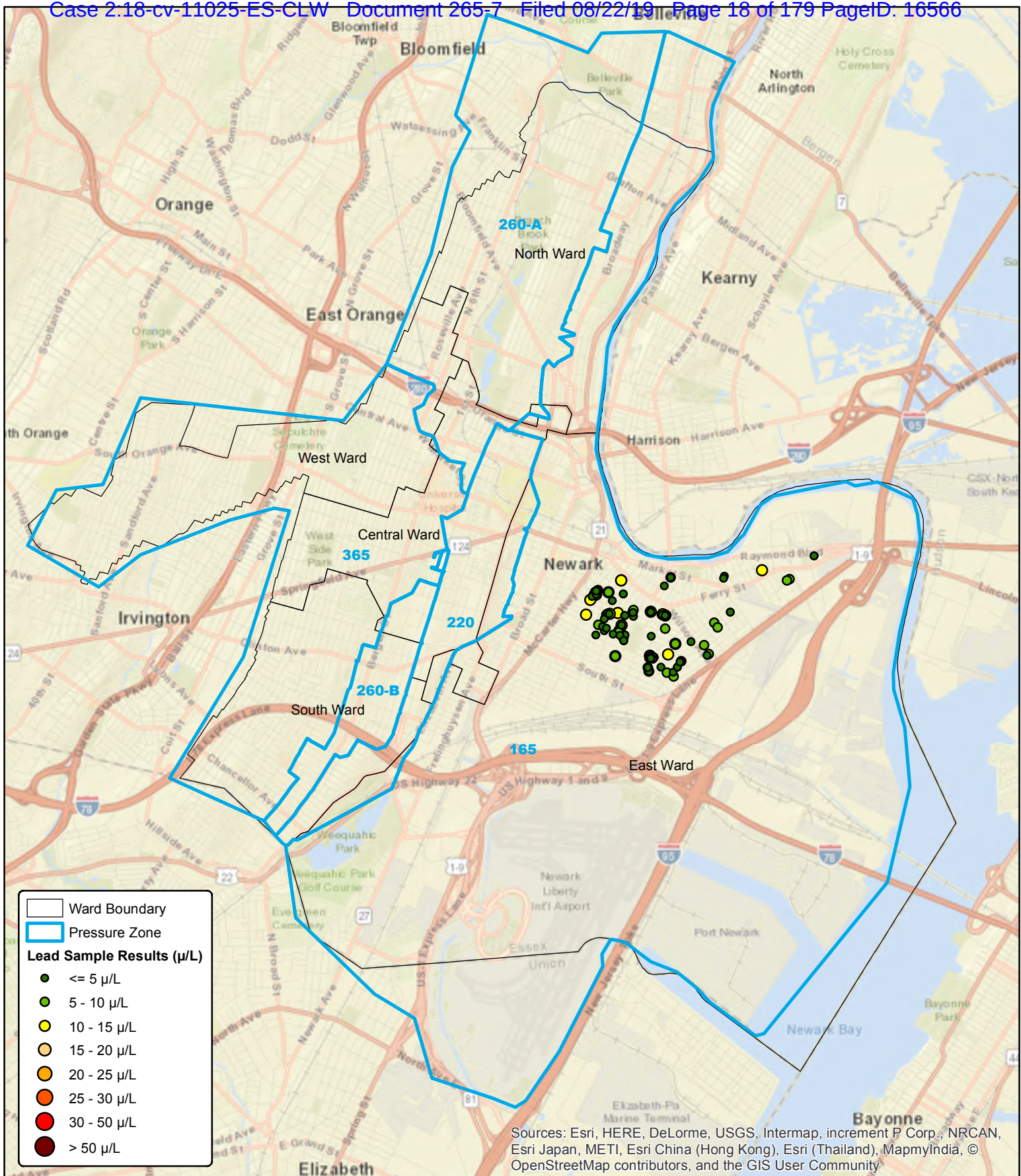
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Lead Level in the City of Newark

Data Collected: 1998

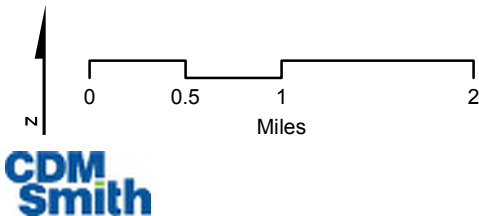
Figure 1-3

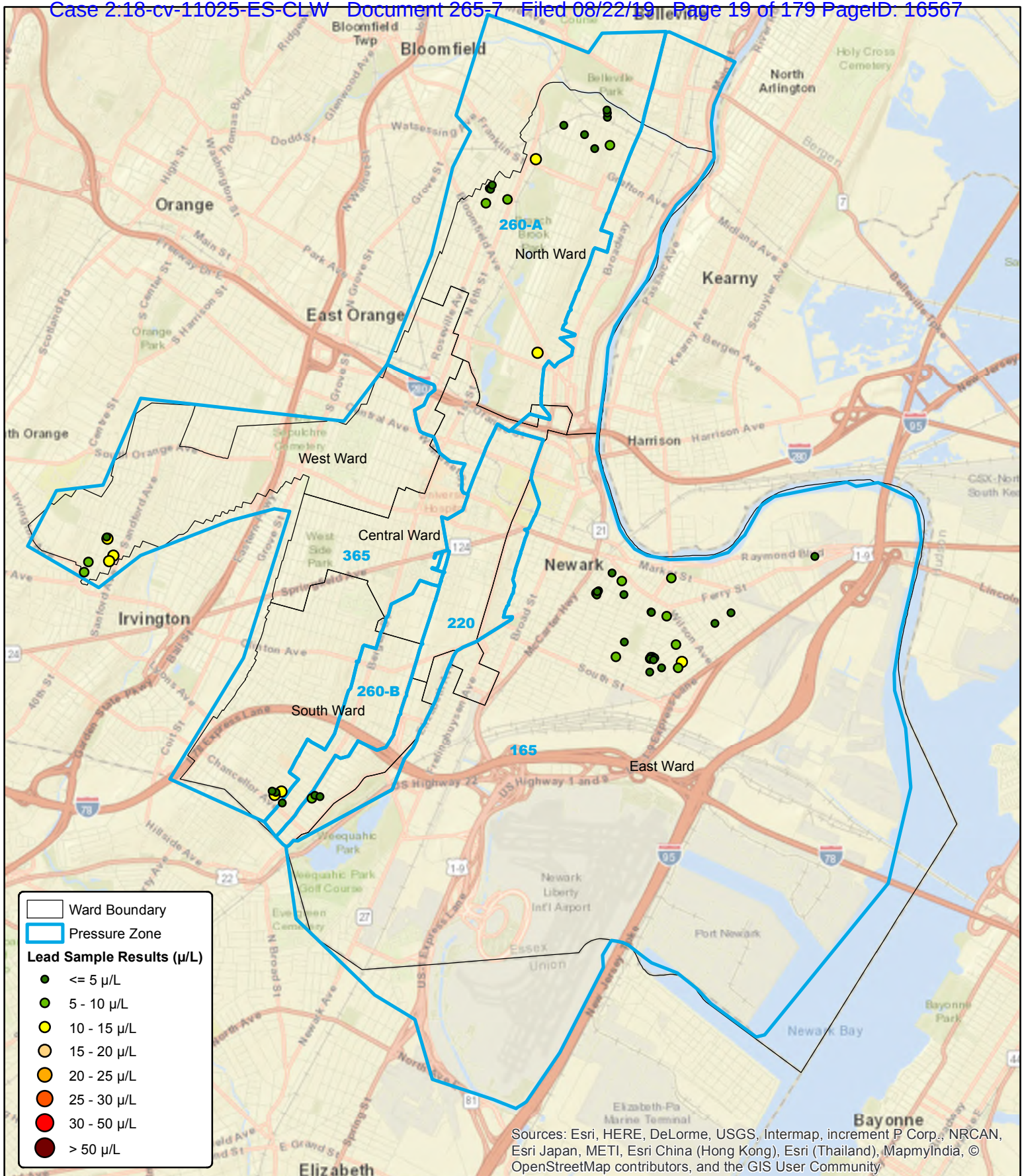


Lead Level in the City of Newark

Data Collected: 2002

Figure 1-4





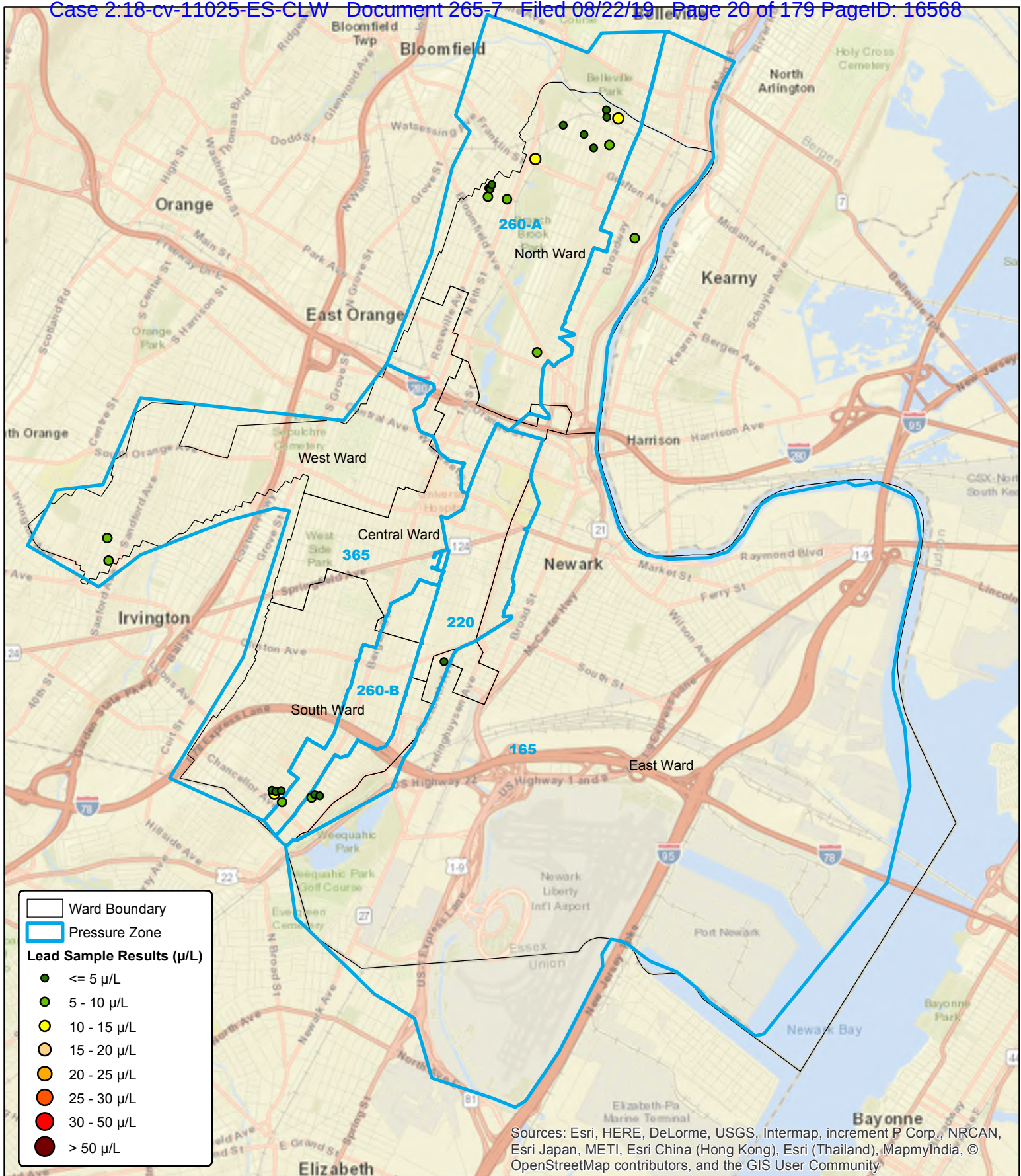
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Lead Level in the City of Newark

Data Collected: 2003

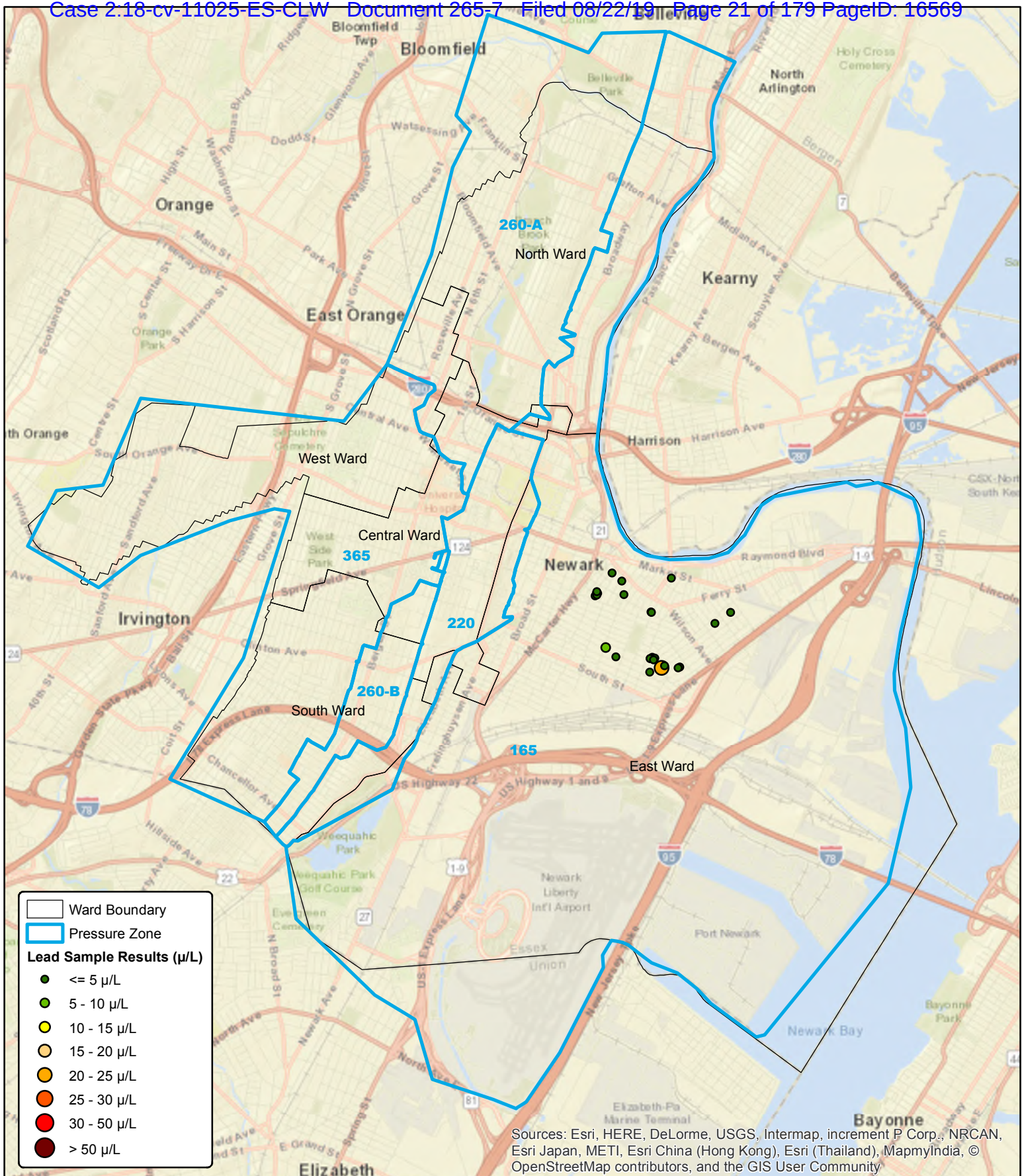
Figure 1-5



Lead Level in the City of Newark

Data Collected: 2006

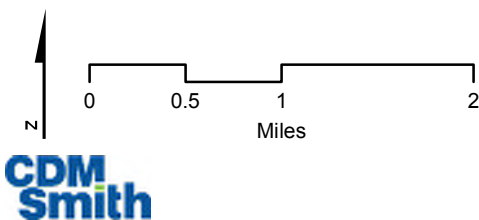
Figure 1-6

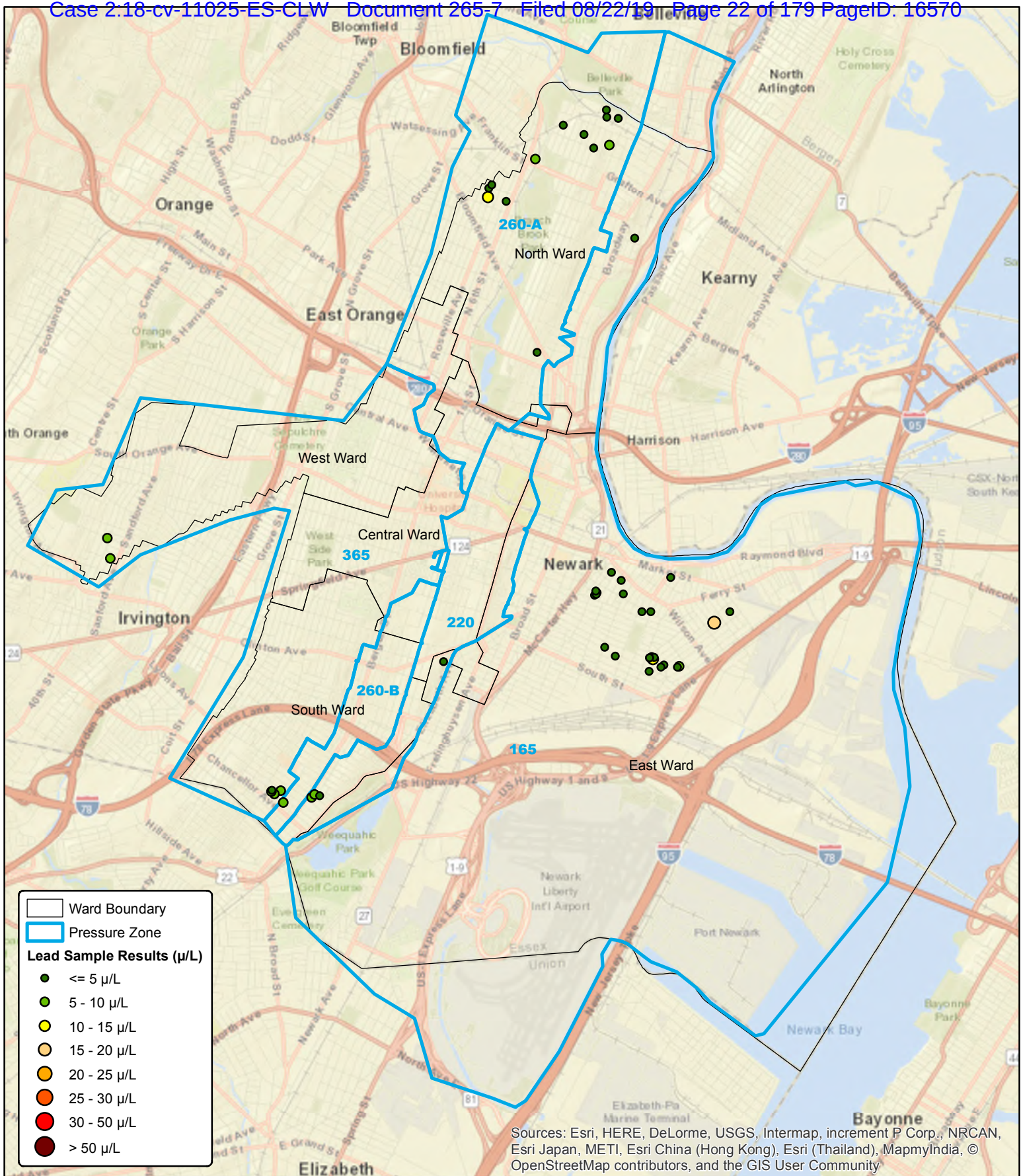


Lead Level in the City of Newark

Data Collected: 2009

Figure 1-7

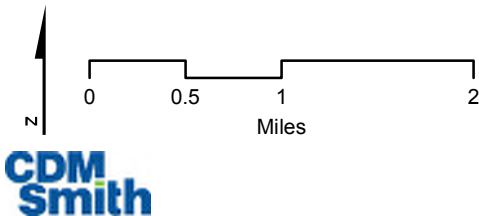


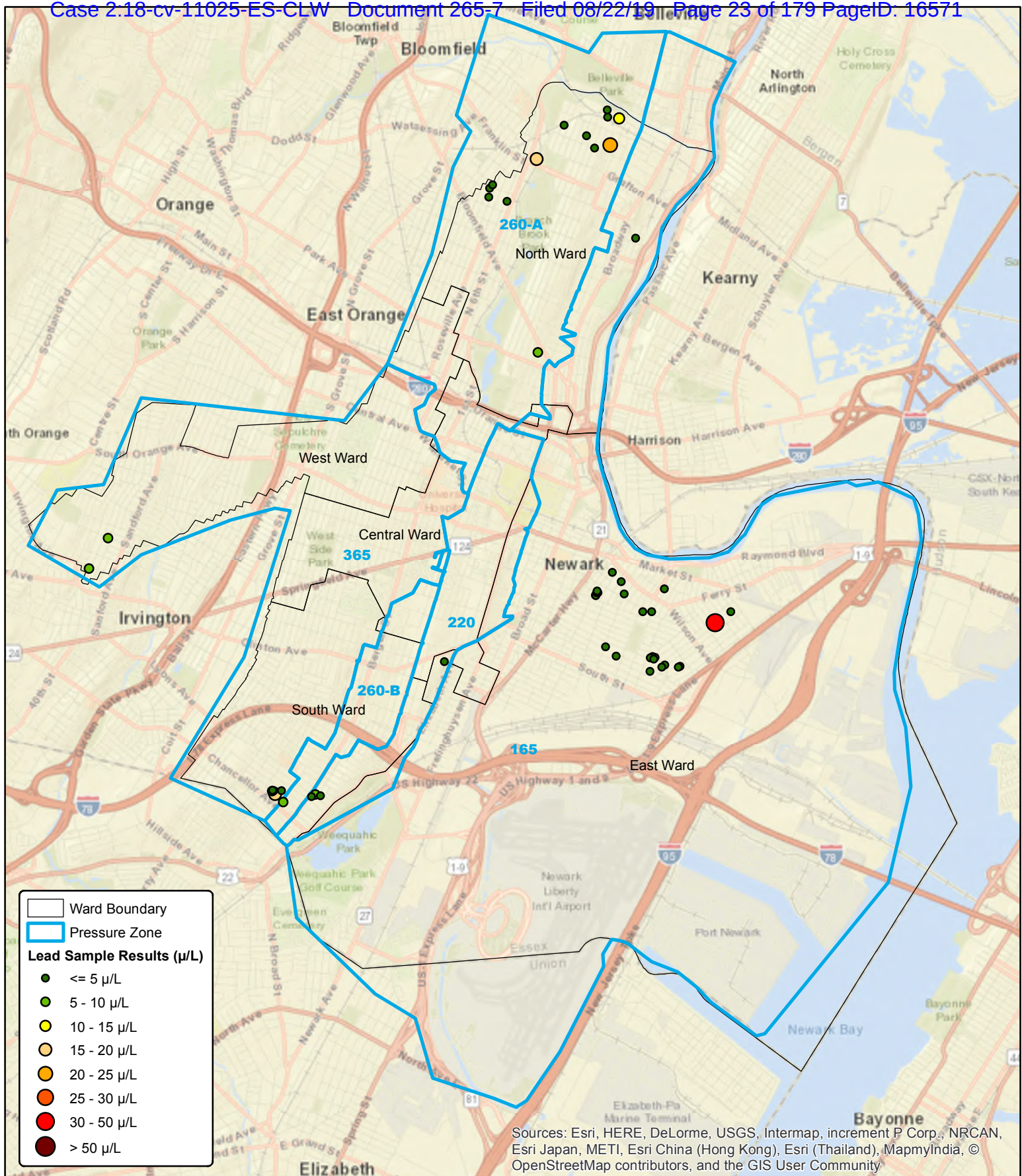


Lead Level in the City of Newark

Data Collected: 2012

Figure 1-8

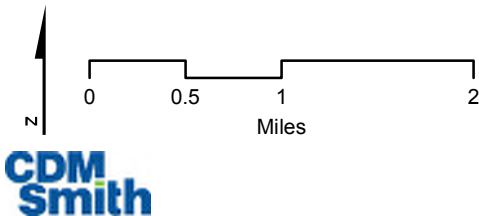


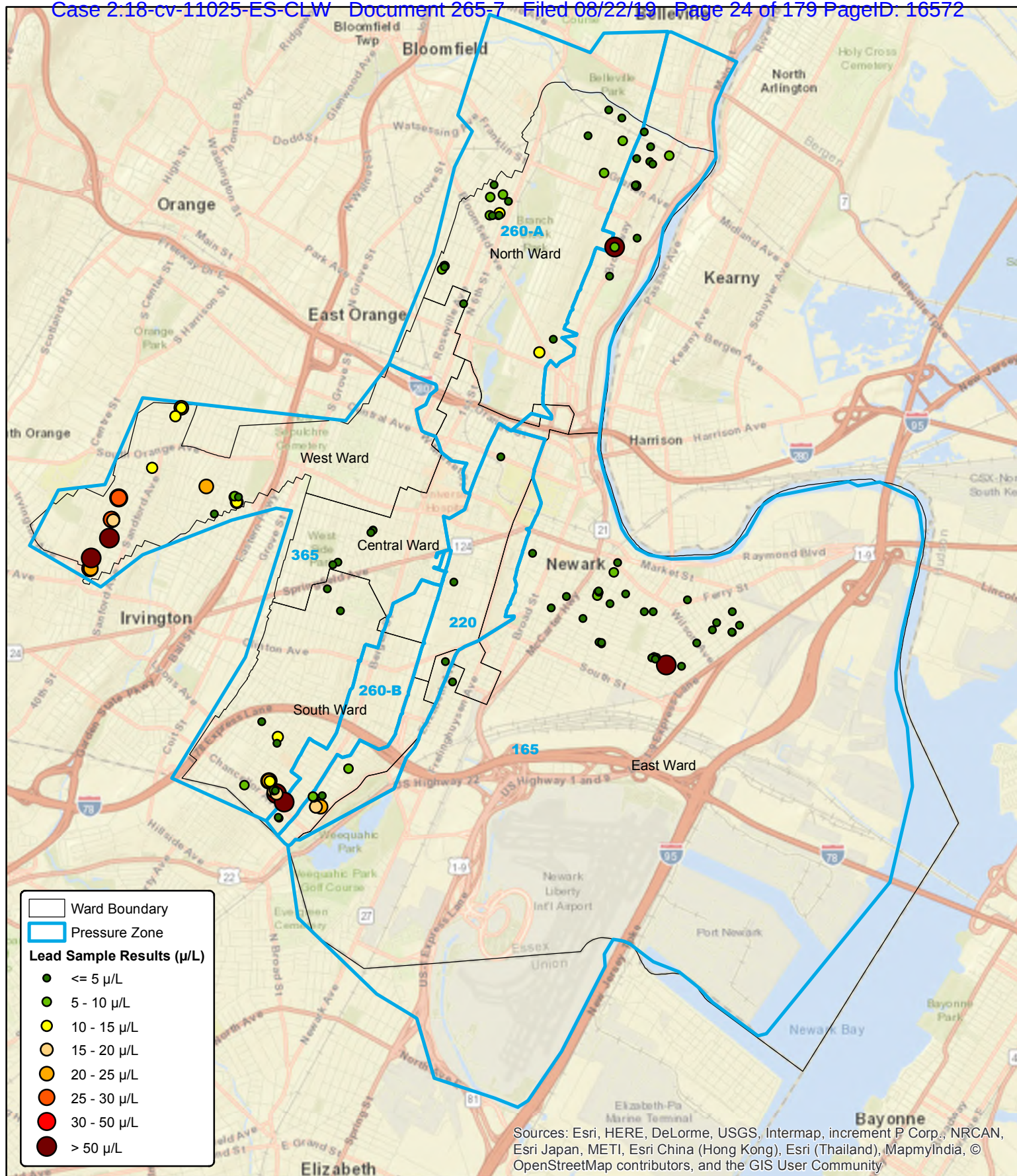


Lead Level in the City of Newark

Data Collected: 2015

Figure 1-9





Lead Level in the City of Newark

Data Collected: January - June 2017

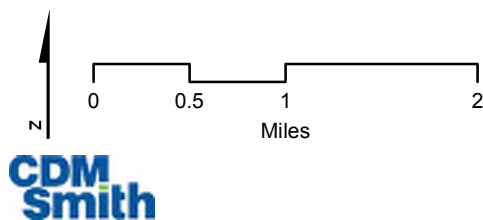
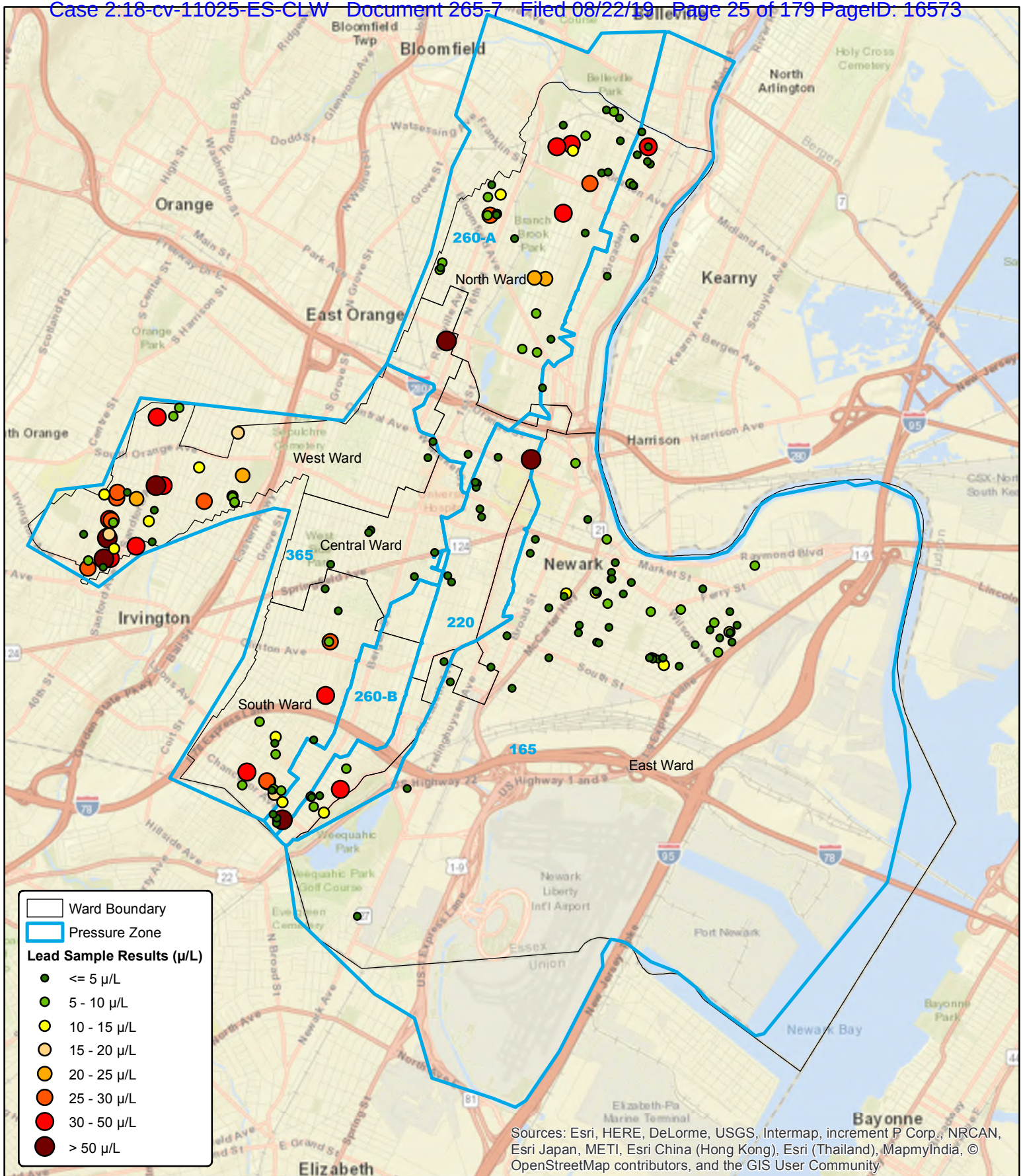


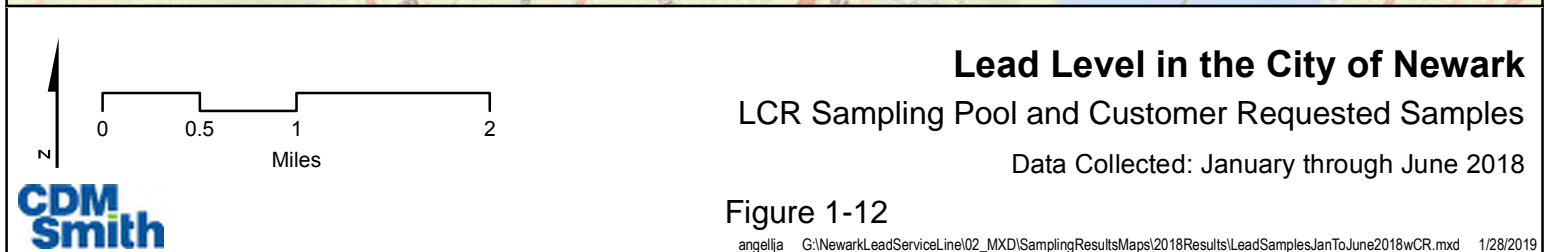
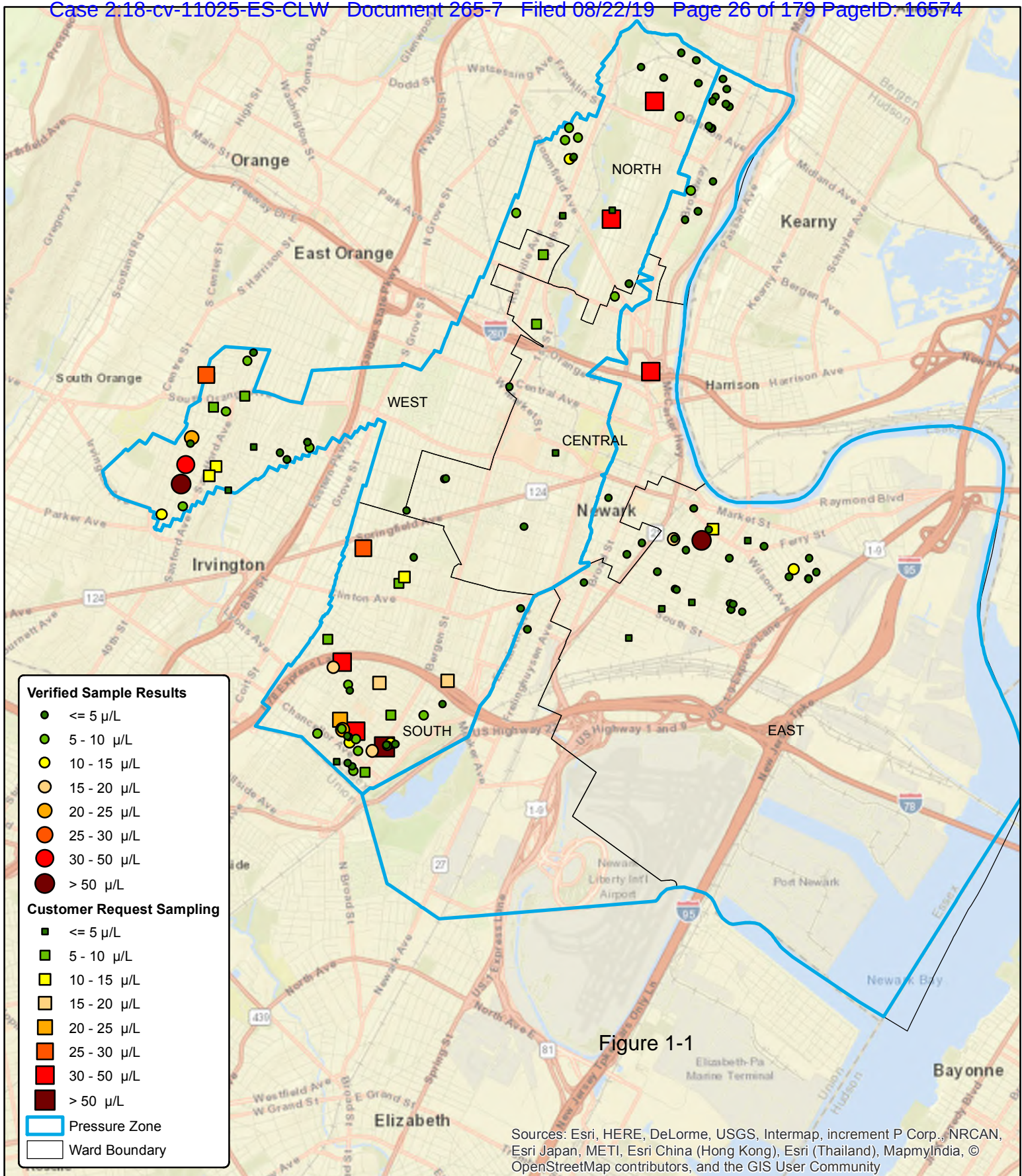
Figure 1-10

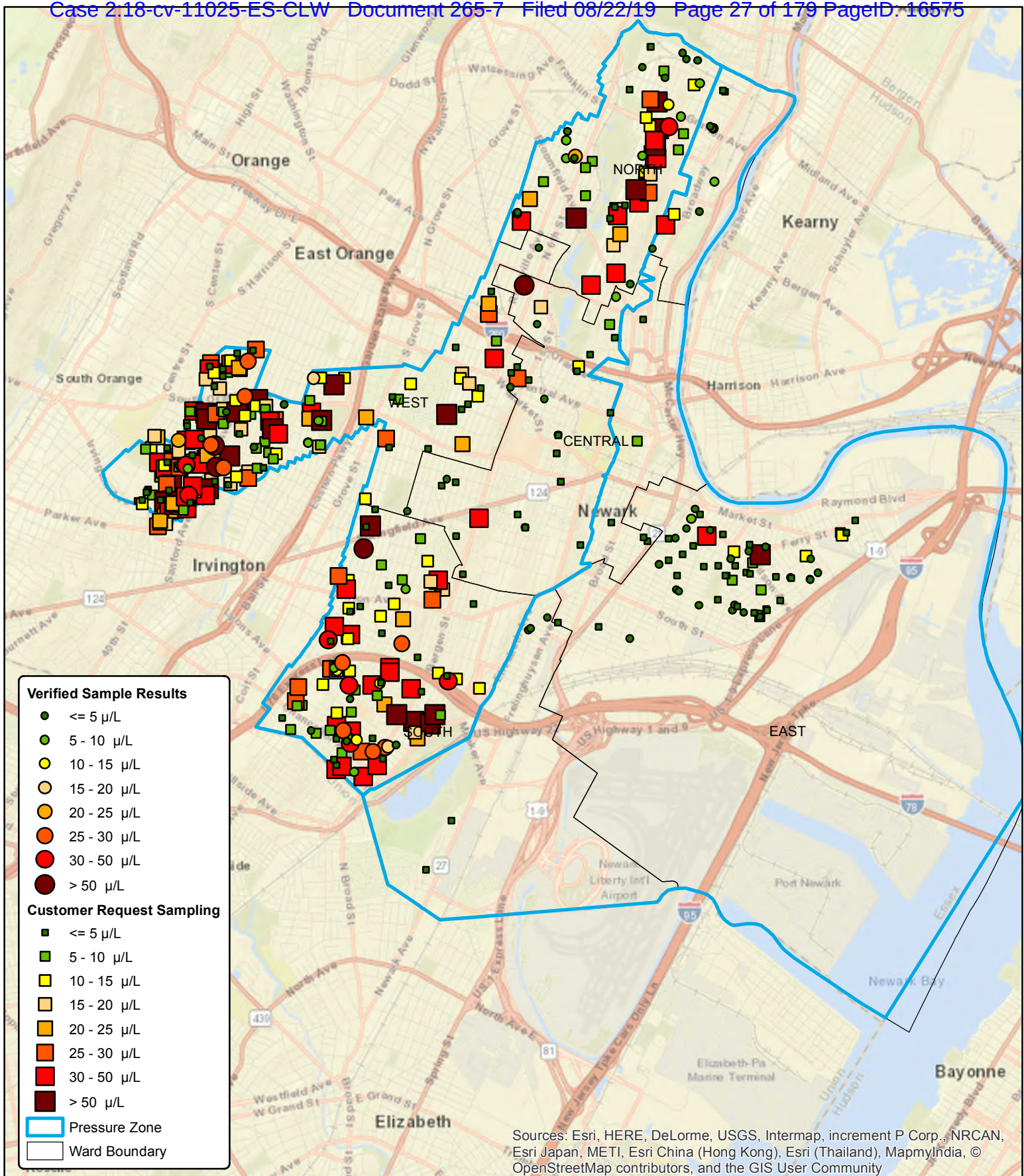


Lead Level in the City of Newark

Data Collected: July - December 2017

Figure 1-11





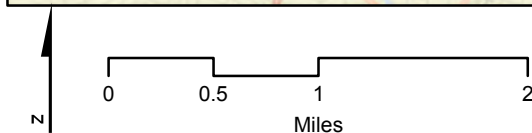
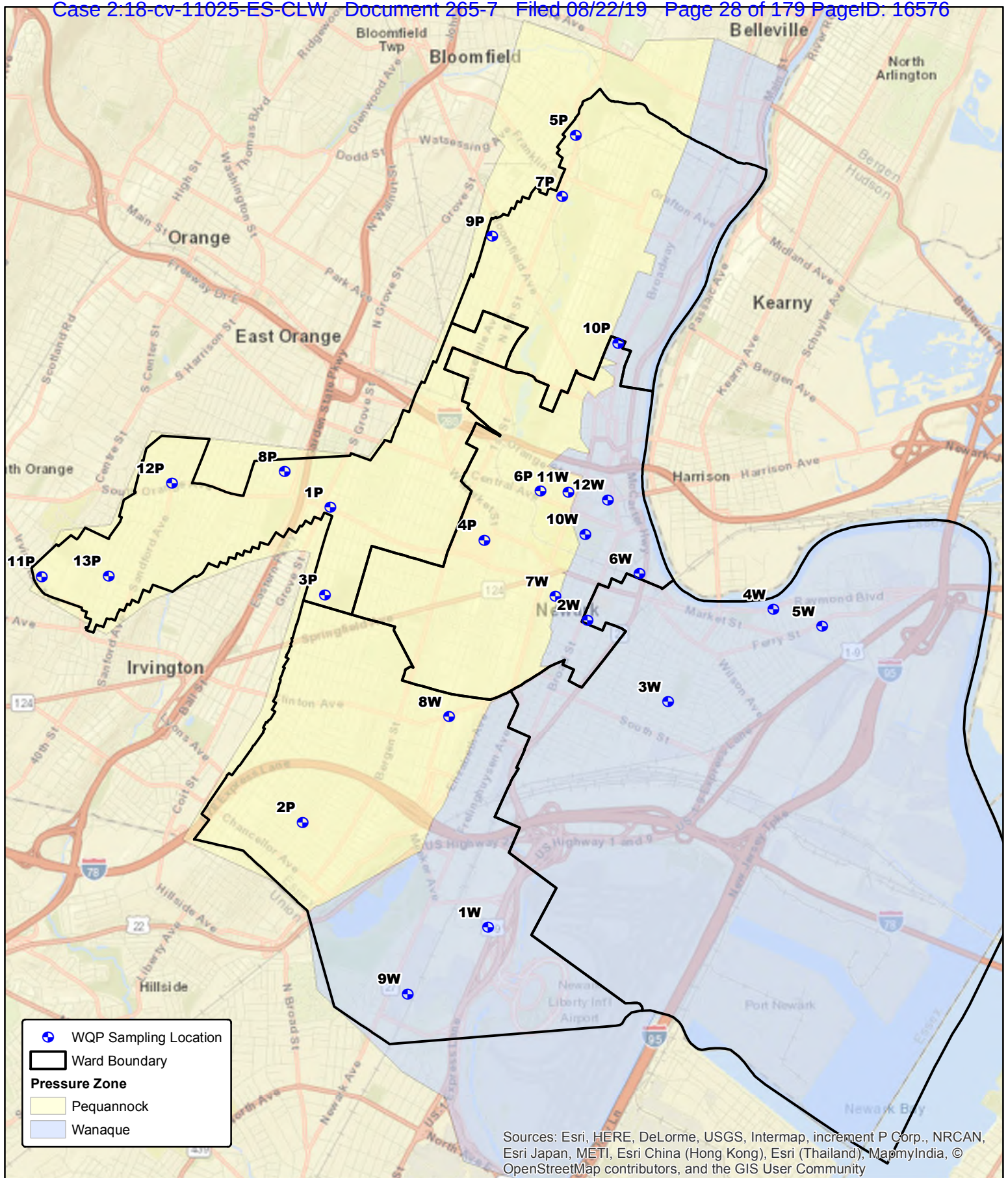
Lead Level in the City of Newark

LCR Sampling Pool and Customer Requested Samples

Data Collected: July through December 2018

Figure 1-13





Newark WQP Sampling Locations

This page intentionally left blank.

Section 2

Lead Frequency Distribution

A frequency distribution analysis was conducted using multiple rounds of compliance sampling data for both the Pequannock and Wanaque service areas. The analysis was conducted for each service area separately as the service areas receive different CCT as described in Section 1.

Although regulatory compliance is based on the City of Newark as a whole, the corrosion control chemistry of the two service areas differ. Therefore, the systems were evaluated separately to understand the cause of the high lead levels found in homes within the City of Newark with lead service lines and/or plumbing components containing lead.

Frequency distributions can provide insight as to whether changes in lead levels may be the result of CCT, sampling variability, or a combination of the two (Burlingame, 2004). Frequency distributions can assist in establishing the cause of a change in the 90th percentile value and AL exceedance. The frequency distribution presented in this Section provides an analysis of the lead sampling results collected since 1992. The data were sorted into several “bins” and percentile categories by lead concentration. The three “bins” that provide the best indication of whether or not CCT has been optimized are: (1) percent less than or equal to 5 µg/L, (2) 50th (median) percentile (µg/L), and (3) percent greater than 15 µg/L and less than or equal to 25 µg/L. Overall trends are also revealed by the frequency distribution data.

This section presents an updated frequency distribution to the October 2018 report and includes the second half of 2018 sampling for the Pequannock and Wanaque service areas.

2.1 Lead Frequency Distribution – Pequannock Service Area

For the Pequannock service area, the frequency distribution analysis was conducted for compliance sampling data collected in 1992, 1998, 2003, 2006, 2012, 2015, the two sampling periods in 2017, and the two sampling periods in 2018. Lead sampling rounds were also conducted by the City of Newark in 2002 and 2009; however, not enough samples were available in the Pequannock Gradient for a statistical analysis in those two years likely based on customer responsiveness.

Figure 2-1 provides an overview of the lead sampling compliance data from the ten (10) sampling events for the Pequannock service area for the different “bins” from less than 5 µg/L to greater than 50 µg/L. **Table 2-1** provides a summary of some statistical parameters based on the lead sampling compliance data, and **Table 2-2** provides an interpretation of the findings of the frequency distribution analysis for the Pequannock service area.

Section 2 • Lead Frequency Distribution

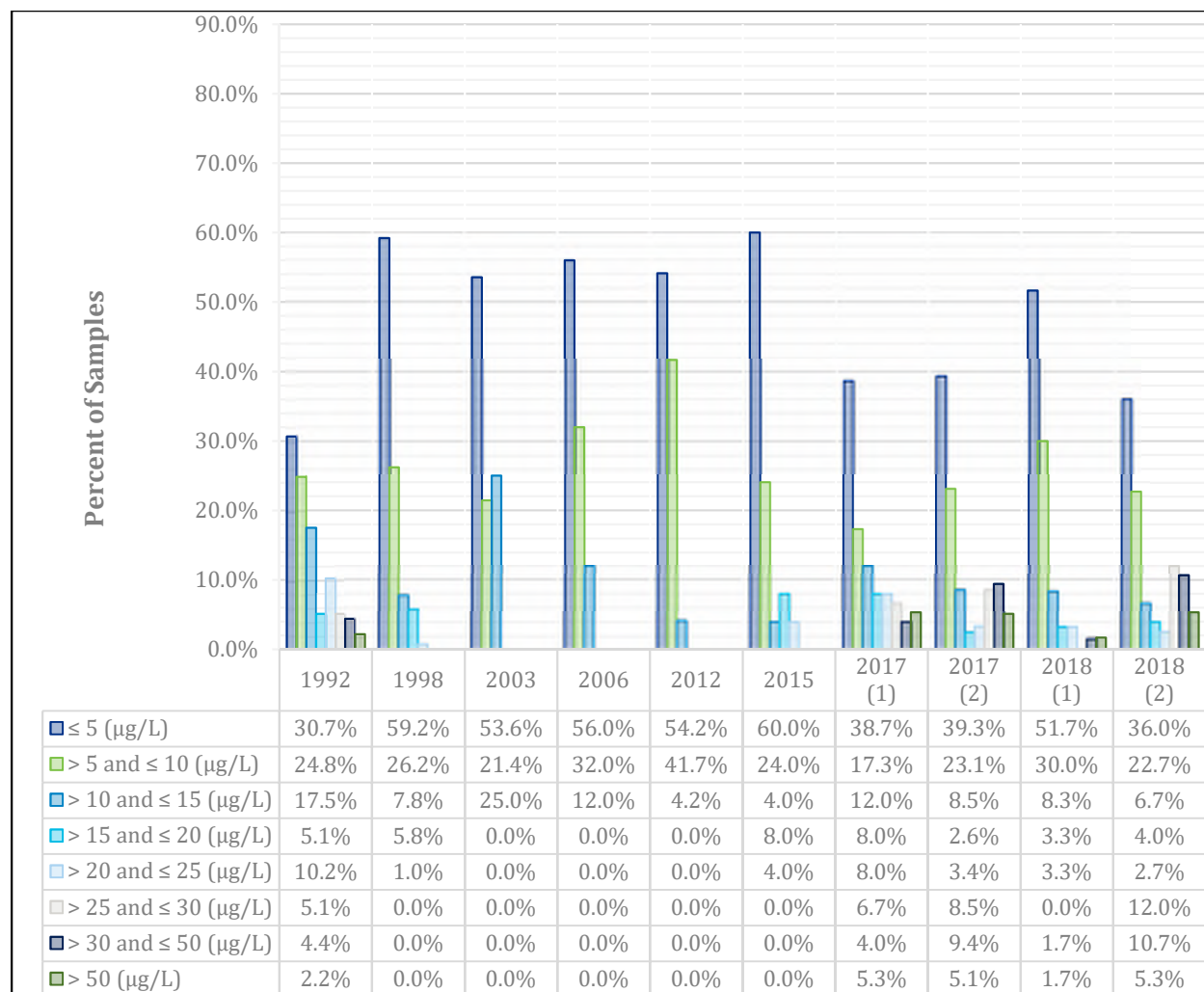


Figure 2-1 – Pequannock Service Area – Lead Sampling Data Percentage Frequency Distribution

Table 2-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data

Parameter	1992	1998	2003	2006	2012	2015	2017 (1)	2017 (2)	2018 (1)	2018 (2)
50th Percentile	8.5	4.0	4.8	4.1	5.0	0.0	7.4	7.8	0.0	7.6
75th Percentile	16.3	7.4	10.0	7.4	7.3	8.0	17.8	21.2	8.2	27.7
90th Percentile	26.8	12.3	12.2	9.5	9.7	15.8	29.8	36.0	14.8	39.5
Number of Samples (n)	137	103	28	25	24	25	75	117	60	75
Number of Samples >15 (n)	37	7	0	0	0	3	24	34	6	26
Percent > 15 and ≤ 25 (µg/L)	15.3%	6.8%	0.0%	0.0%	0.0%	12.0%	16.0%	6.0%	6.7%	6.7%
Maximum (µg/L)	60.4	23.0	14.2	11.5	14.0	25.0	137.0	77.7	52.6	72.2

Table 2-2 – Pequannock Service Area Frequency Distribution Analysis

Data Category/Bin	What does it tell us?	Newark Pequannock Pb Results
Overall frequency distribution	Gives a comprehensive picture of sampling results and allows for comparisons over different periods of time.	The Pequannock WTP implemented sodium silicate chemical addition for CCT in 1997. The lead results from 1998 through 2012 reflect effective control of lead release. However, starting in 2015, lead levels returned to and, in some cases, exceeded 1992 levels. This points to a significant change in system behavior around 2015.
Less than or equal to 5 µg/L	Typically, optimization of a corrosion control treatment is signified by an increased percentage of values that are less than 5 µg/L. When water is treated to be less corrosive, or chemistry is modified to create a stable and insoluble lead compound, overall lead levels will decrease, thereby increasing the percentage of samples with the lowest lead concentrations.	The percentage of samples less than or equal to 5 µg/L increased after CCT was implemented (1997). However, this category only saw 60% of the samples at best, compared to optimized systems which typically see well above 80% of samples less than 5 µg/L. In 2017 and the second half of 2018, the number of samples less than 5 µg/L decreased significantly from 50-60% to slightly less than 40%.
50th percentile (µg/L)	The nature of the 90th percentile Action Level is such that it only takes a few samples to greatly affect the outcome of a monitoring period. One seemingly benign deviation in the sampling protocol can greatly skew the 90th percentile value. The 50th percentile is much more resilient and, as such, is a good indicator of the relative effectiveness of a CCT.	The 50 th percentile value decreased from 1992 levels by about half after CCT was implemented in 1997. However, the 50 th percentile nearly doubled in 2017 and the second half of 2018.
Greater than 15 µg/L and less than or equal to 25 µg/L	A small deviation within the 15 to 25 ppb range of samples above could put a system out of compliance. By improving the CCT, a system can provide a greater buffer between the 90th percentile values and the AL of 15 ppb, so as to lessen the effects of an unrepresentative sample.	Prior to implementation of CCT (1992), a significant percentage (15%) of the samples were in this range. After many years of no results being in this range, an uptick in results between 15 and 25 ppb began in 2015, continuing to the first half of 2017; and were still elevated thereafter but slightly less than between 2015 and the first half of 2017. This may be indicative that the most significant impact to the pipe scales may have peaked by early 2017, but this cannot be confirmed.

2.2 Lead Frequency Distribution – Wanaque Service Area

A frequency distribution analysis was conducted for compliance sampling data collected in 1992, 2002, 2009, 2012, 2015, the two sampling periods in 2017, and the two sampling periods in 2018 for the Wanaque service area. Lead sampling rounds were also conducted by the City of Newark in 1998 and 2003; however, not enough samples were available in the Wanaque Gradient for a statistical analysis in those two years likely based on customer responsiveness.

Figure 2-2 provides an overview of the lead sampling compliance data from the ten (10) sampling events for the Wanaque service area for the different “bins” from less than 5 µg/L to greater than 50 µg/L. **Table 2-3** provides a summary of some statistical parameters based on the lead sampling compliance data, and **Table 2-4** provides an interpretation of the findings of the frequency distribution analysis for the Wanaque service area.

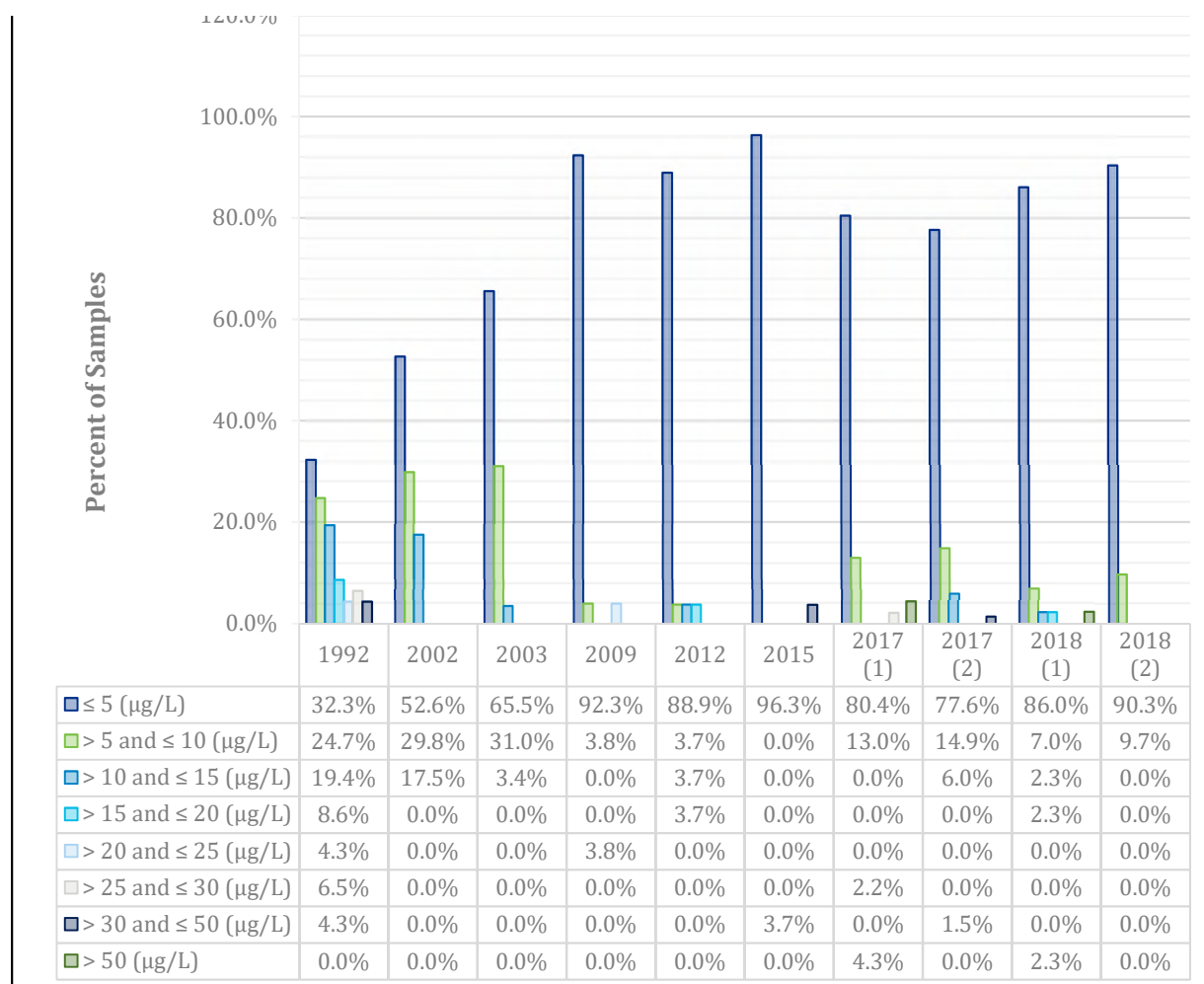


Figure 2-2 – Wanaque Service Area – Lead Sampling Data Percentage Frequency Distribution

Table 2-3 – Summary of Statistical Parameters for Wanaque Lead Sampling Data

Parameter	1992	2002	2003	2009	2012	2015	2017 (1)	2017 (2)	2018 (1)	2018 (2)
50th Percentile	6.6	4.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75th Percentile	14.2	9.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90th Percentile	25.7	11.2	8.4	0.0	6.2	2.0	7.4	8.7	7.0	4.1
Number of Samples (n)	93	114	29	26	27	27	46	67	49	31
Number of Samples >15 (n)	22	0	0	1	1	1	3	1	2	0
Percent > 15 and ≤ 25 (µg/L)	12.9%	0.0%	0.0%	3.8%	3.7%	0.0%	0.0%	0.0%	2.3%	0.0%
Maximum (µg/L)	49.4	14.9	12.3	24.6	19.0	37.0	84.0	46.1	182.0	9.3

Table 2-4 – Wanaque Service Area Frequency Distribution Analysis

Data Category/Bin	What does it tell us?	Newark Wanaque_Pb Results
Overall frequency distribution	Gives a comprehensive picture of sampling results and allows for comparisons over different periods of time.	The Wanaque WTP implemented zinc orthophosphate chemical addition for CCT treatment in the mid 1990s. Between 1992 and 2018, lead sampling results for the Wanaque service area shifted in multiple “bins” (ranges). The 1992 sampling was prior to the CCT treatment improvements. These results point to CCT effectiveness as the cause of a significant decrease in action level beginning in the early 2000s and a shift in the percentage of results into lower bins.
Less than or equal to 5 µg/L	Typically, optimization of a corrosion control treatment is signified by an increased percentage of values that are less than 5 µg/L. When water is treated to be less corrosive, or chemistry is modified to create a stable and insoluble lead compound, overall lead levels will decrease, thereby increasing the percentage of samples with the lowest lead concentrations.	Between 1992 and 2018, there was a large increase in % of samples in this category. Where 1992 saw 32% of samples in this category, 2017 and 2018 sampling saw an increase to an average of 84% between the four sampling pools for lead results less than or equal to 5 ppb. This can again be tied to CCT treatment of zinc orthophosphate. Typically, optimized systems have a majority of sample results (>80%) in the category of <5 ppb.

Data Category/Bin	What does it tell us?	Newark Wanaque_Pb Results
50th percentile ($\mu\text{g/L}$)	The nature of the 90th percentile Action Level is such that it only takes a few samples to greatly affect the outcome of a monitoring period. One seemingly benign deviation in the sampling protocol can greatly skew the 90th percentile value. The 50th percentile is much more resilient and, as such, is a good indicator of the relative effectiveness of a CCT.	The 50 th percentile value decreased from 6.6 in 1992 to zero (0) in 2009, and has remained as such ever since indicating effectiveness of the zinc orthophosphate CCT treatment.
Greater than 15 $\mu\text{g/L}$ and less than or equal to 25 $\mu\text{g/L}$	A small deviation within the 15 to 25 $\mu\text{g/L}$ range could put a system out of compliance. By improving the CCT, a system can provide a greater buffer between the 90th percentile values and the AL of 15 $\mu\text{g/L}$, so as to lessen the effects of an unrepresentative sample.	There was a large decrease in the number of results in this category after the initial sampling round in 1992, which was prior to implementation of CCT. In 2009, 2012 and first half of 2018, there was a slight increase in this category, which could indicate sampling variability but not definitively. Overall, occurrences of lead levels above the action level decreased significantly indicating the effectiveness of the CCT treatment.

2.3 Service Area Comparison

When separating the LCR compliance sampling data for the Pequannock and Wanaque Gradients, it is clear from the results of the individual lead frequency distribution analyses that a large majority of the lead exceedances have occurred in the Pequannock service area. The frequency of lead exceedances in Pequannock alone has triggered the lead AL exceedances for the City of Newark since the first half of 2017. If the Pequannock and Wanaque Gradients were regulated independently, the Wanaque service area was in compliance with the Lead and Copper Rule from 2002 to present with 90th percentile values ranging from 0.0 to 11.2 $\mu\text{g/L}$ over that period. Over that same period, the Pequannock 90th percentile values ranged from 9.5 to 39.5 $\mu\text{g/L}$. In the most recent sampling round, the second half of 2018, the Pequannock 90th percentile based on the verified LCR sampling pool was 39.5 $\mu\text{g/L}$ and the Wanaque 90th percentile based on the verified LCR sampling pool was 4.12 $\mu\text{g/L}$.

If the customer requested samples are included in a 90th percentile calculation with the LCR compliance samples, the lead results in the first and second half of 2018 are higher but still indicate a major difference between the Pequannock and Wanaque Gradients. The Pequannock 90th percentile calculation for all samples (LCR compliance and customer requests) is 23.62 $\mu\text{g/L}$ for the first half of 2018 and 46.74 $\mu\text{g/L}$ for the second half of 2018. The Wanaque 90th percentile calculation for all samples (LCR compliance and customer requests) is 8.68 $\mu\text{g/L}$ for the first half of 2018 and 9.61 $\mu\text{g/L}$ for the second half of 2018. This calculation includes homes where the materials are not verified and are, therefore, not included in the official LCR compliance

calculation. A 90th percentile calculation with customer requests is not a compliance requirement and is presented herein only to show the 90th percentile with an expanded pool of data.

The historic LCR compliance sampling data, as well as the data recently collected as part of this study, show that the current CCT for the Wanaque service area is able to consistently reduce lead levels in the drinking water to below the lead AL.

Due to the determination that the Pequannock system is triggering the lead AL exceedances for the City of Newark, the study on the Pequannock system was prioritized and submitted in draft form in October 2018 to the NJDEP and submitted as final in March 2019. The Pequannock report evaluated the cause of the elevated lead levels and provided recommendations for reducing lead levels in the Pequannock system, which are currently being implemented.

Since, as a whole, the entire City of Newark is not currently meeting the lead AL due to the Pequannock/Wanaque combined reporting, a more detailed report was requested by NJDEP providing further analysis on the Wanaque Gradient, including sequential sampling and pipe scale analyses. Based on the analyses herein, recommendations for optimization of the CCT in the Wanaque Gradient and recommendations to reduce the public's exposure to lead in drinking water in the Wanaque service area are provided in Section 6.

f

Section 3

Water Quality

Historic water quality data was obtained from NJDEP Drinking Water Watch (as of June 12, 2019) and is summarized in this section. Data from PWSID NJ0714001 (Newark Water Department) and PSWID NJ1613001 (NJDWSC – Wanaque North) were used. Data were also obtained from Newark’s WQP sampling locations in the Wanaque Gradient between July 2016 and April 2019.

The following subsections review the water quality of the Wanaque Gradient’s point of entry (POE) and within Newark’s distribution system.

3.1 Wanaque Gradient Point of Entry (POE) Water Quality Data

This section provides water quality data and analyses pertinent to the analysis of corrosion control treatment.

3.1.1 Belleville Data

To compare with the Pequannock water supply entering Newark’s distribution system, silica, pH and orthophosphate were evaluated at the Belleville POE. Silica data was provided by NJDWSC for the raw water entering the Wanaque WTP. Raw water silica was analyzed on a quarterly basis between 2016 and 2018. Silica concentrations appear to be seasonal, similar to Pequannock, with higher concentrations in the winter and lower concentrations in the summer, with an average silica concentration of approximately 2 to 3 mg/L.

NJDWSC also provided pH and orthophosphate data between July 2016 and December 2018 leaving the Belleville Complex. This data is summarized in **Table 3-1**. **Figure 3-1** demonstrates the pH and orthophosphate trends between July 2016 and December 2018.

Table 3-1 – Water Quality Ranges for Wanaque POE and Raw Water Silica

Sample ID	Silica (mg/L) – Raw	pH - Belleville	Orthophosphate (mg/L as PO ₄) - Belleville
minimum	0.74	7.38	1.26
average	2.03	7.78	1.76
maximum	3.53	8.48	2.88

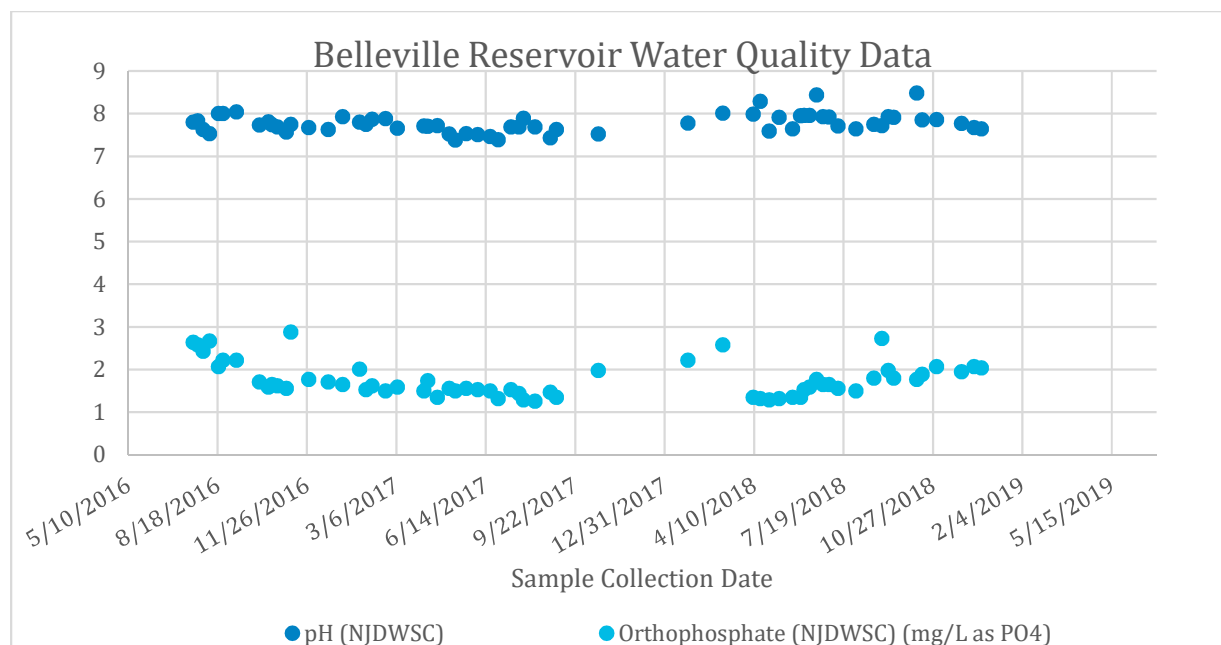


Figure 3-1 – Belleville Water Quality Data Trend

The data indicates that NJWSC maintains a fairly consistent pH and orthophosphate residual at Newark's POE at approximately 7.8 and 1.76 mg/L (as PO₄), respectively, from the Wanaque system with occasional variations in pH or orthophosphate.

3.2 Wanaque Gradient Distribution System Water Quality Data

As mentioned in Section 1, Newark has been monitoring WQPs since July 2016 on a regular basis at several sampling locations. This includes points of entry into the distribution system (Sample House (PWTP), [REDACTED], Montclair Re-chlorination Station and the Belleville Reservoir Complex) on a bi-weekly basis and 25 sampling locations in the distribution system on a quarterly basis. The sampling locations for monitoring Newark's distribution system WQPs were presented in **Figure 1-14**. There are 13 WQP sampling locations in the Pequannock service area (labeled with "P") and 12 WQP sampling locations in the Wanaque service area (labeled with "W"). However, based on the addresses provided for these sample locations, it appears that the following WQPs may have been labeled incorrectly, and are currently being modified with NJDEP.

- 2W – Labeled as Wanaque but in the Pequannock service area
- 8W – Labeled as Wanaque but in the Pequannock service area
- 11W – Labeled as Wanaque but in the Pequannock service area
- 10P – Labeled as Pequannock but in the Wanaque service area

The water quality data for the 25 WQP sampling locations in the distribution system were provided between July 2016 and December 2018. The WQPs for the distribution system are reported on a quarterly basis. **Table 3-2** summarizes statistics for pH, alkalinity, orthophosphate

and silica at the WQP distribution sampling locations in the Pequannock and Wanaque Gradients. Sampling locations 2W, 8W and 11W are included with Pequannock's data and sampling location 10P is included with Wanaque data based on their physical locations in the system.

Table 3-2 – Pequannock and Wanaque Gradient WQP Distribution System Water Quality (July 2016 – December 2018)

Parameter	Pequannock			Wanaque		
	Min	Avg	Max	Min	Avg	Max
pH	6.69	7.46	8.73	6.86	7.52	8.30
Alkalinity (mg/L as CaCO ₃)	21.40	30.51	59.30	21.30	33.63	51.60
Orthophosphate (mg/L as PO ₄)	ND	0.10	1.39	ND	0.52	2.37
Silica (mg/L as Silica)	3.70	6.21	8.80	1.24	4.94	8.19

As can be seen in **Table 3-2**, there are some similarities and some distinct differences between the water quality in the Pequannock Gradient and the Wanaque Gradient. Some observations include:

- The pH values are very similar between the Pequannock and Wanaque Gradients; however, the Wanaque Gradient appears to have a more consistent pH than the Pequannock Gradient.
- Average alkalinity in the Wanaque Gradient is slightly higher at 34 mg/L as CaCO₃ than the Pequannock Gradient at 31 mg/L as CaCO₃; however, the seasonal variations are similar.
- Orthophosphate residual is significantly higher in the Wanaque Gradient than the Pequannock Gradient, although lower on average than at the target dose of 1.8 mg/L to 2.2 mg/L as PO₄ at the POE leaving the Belleville Reservoir Complex. The Pequannock Gradient occasionally gets water with orthophosphate from one of its interconnections with PVWC or Jersey City which may explain the PO₄ concentrations that appear in limited samples in the Pequannock.
- The silica concentration is significantly higher for the Pequannock Gradient on average than the Wanaque Gradient, although the maximum values are similar.

3.2.1 Wanaque and Pequannock Mixing

There are two known ways that water can flow from the Pequannock Gradient to the Wanaque Gradient. Specifically, there are forty-seven (47) division gate valves and eight (8) pressure regulating valves within the Newark distribution system that can send water from Pequannock to Wanaque on an as needed basis. These valves are closed under normal operating conditions and are intended to separate Wanaque and Pequannock Gradients. Division gates are operated manually whereas pressure regulating valves open and close automatically based on a set pressure differential between the two gradients. These valves provide added resiliency to

Newark's water distribution system as they can divert water to areas in need on a temporary basis, such as a water main break, low flow condition, or emergency such as a fire. Since the Wanaque Gradient is lower (165 feet) compared with the Pequannock Gradient (over 200 feet), water will typically move from the higher Pequannock Gradient to the lower Wanaque Gradient and not from Wanaque to Pequannock unless there were to be a significant drop in pressure in the Pequannock Gradient. From November 2018 through January 2019, the City investigated and evaluated the pressure reducing valves and division gate valves to determine if there were any leaking or malfunctioning valves within the system. It was reported that none of the valves were leaking; however, approximately 6 division gate valves were found to be partially open. Any division gate valve that was found partially open was closed by Newark during this period. It is important to note that the pressure regulating valves must remain active in case of system emergency conditions but are normally in the closed position.

After the division gates were closed, there was a noticeable change in water quality parameters, specifically an increase in orthophosphate residual and decrease in silica concentrations, in several of the WQP locations in the Wanaque Gradient. This can be seen in **Tables 3-3 and 3-4**, which provide the average values for pH, alkalinity, orthophosphate and silica at each Pequannock and Wanaque WQP sampling locations, respectively, from July 2016 to December 2018 and then from March and April 2019 at specific Wanaque locations in **Table 3-4**.

As shown in **Table 3-3**, the WQP sampling location 10P [REDACTED] highlighted in green is confirmed to be sampling water from the Wanaque Gradient and not the Pequannock Gradient as previously thought. This sampling location is proposed to be changed to a Wanaque WQP.

In **Table 3-4**, the highlighted green rows are suspected to be sampling water from the Pequannock Gradient and not the Wanaque Gradient. Even with all of the division gates closed, WQP sampling locations 2W, 8W and 11W had very little to no orthophosphate residual and higher than typical Wanaque silica concentrations.

The water quality data collected after all of the division gates were checked and closed show an appreciable increase in orthophosphate residual and decrease in silica concentration in the WQP locations 3W, 4W, 5W, 6W, 7W, 10W and 12W. This is represented by the yellow highlighted cells. As a result, it is suspected that these sampling locations in the Wanaque Gradient had been "Likely Supplemented by Pequannock" Prior to the closure of the division gates. These locations are indicated on the map shown in **Figure 3-2**.

Based on the lead levels in customer taps as presented in Section 2, the water quality in the Wanaque Gradient, including the lower levels of orthophosphate found in some areas, does not appear to have been impacted to result in an increase in lead levels in the Wanaque Gradient. Once the division gates were closed, the lower levels of orthophosphate seen in portions of the Wanaque Gradient appear to have been addressed.

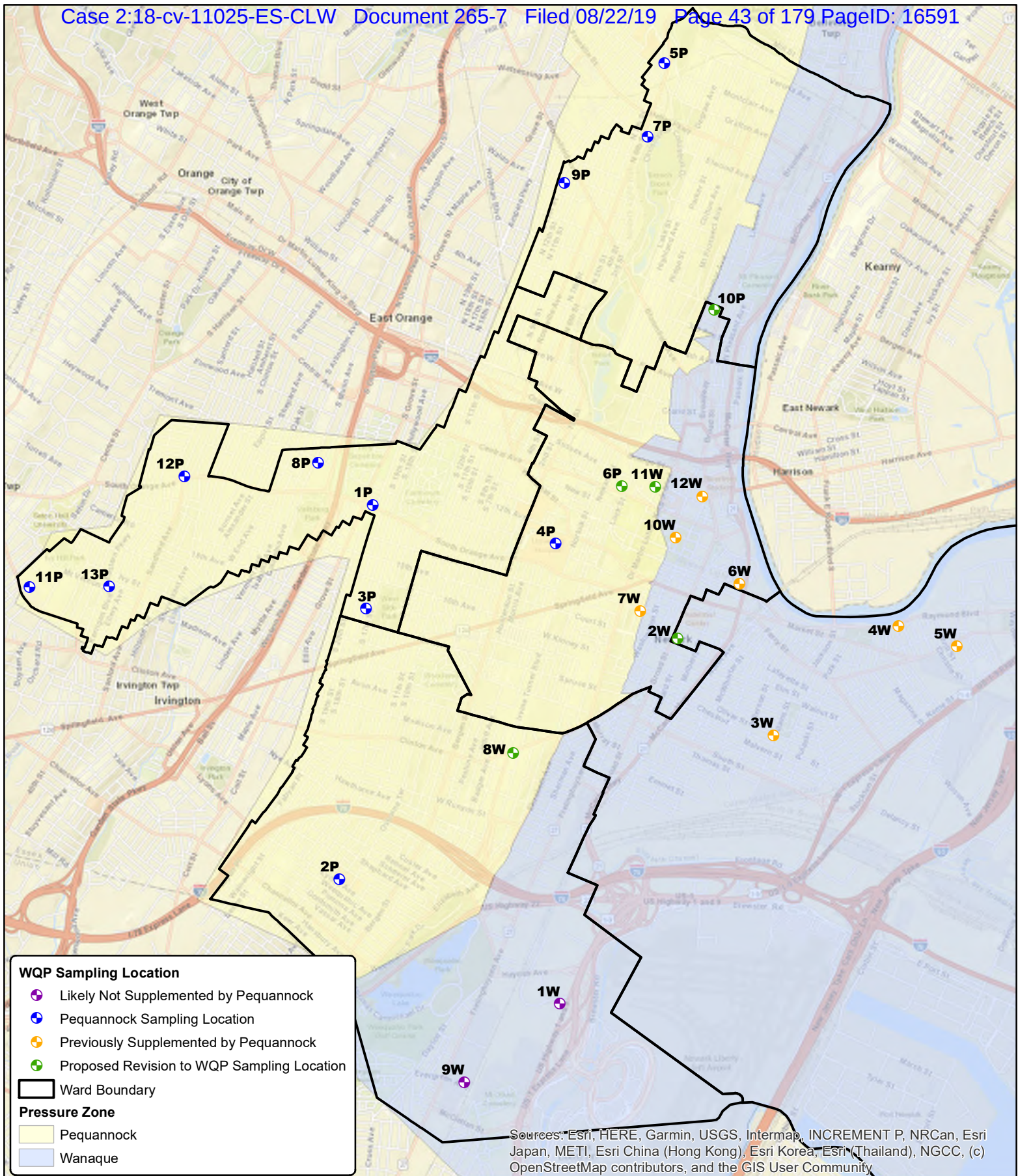
In addition to the above, with orthophosphate now being added in the Pequannock Gradient, any blending of the two sources should not result in diminished orthophosphate residuals.

Table 3-3 - Pequannock WQP Sampling Locations Summary (July 2016 - December 2018)

Sample ID	WQP Sampling Locations	Data Used	Pequannock				Comments
			pH average	Alkalinity (mg/L as CaCO ₃) average	Orthophosphate (PO ₄) average	Silica (mg/L as Silica) average	
TH	Sample House, PWTP	2016-2018	7.11	25.67	0.03	7.95	POE Pequannock
VR	Montclair Rechlorination Stn. [REDACTED]	2016-2018	7.25	29.75	0.01	6.03	POE Pequannock
1P	Senior Home, 545 Orange Street	2016-2018	7.45	29.49	Not measured	6.66	Keep Pequannock WQP
2P	Beth Israel Hospital, 201 Lyons Avenue	2016-2018	7.56	29.66	Not measured	6.31	Keep Pequannock WQP
3P	South 17th School, 619 South 17th Street	2016-2018	7.37	29.50	Not measured	6.53	Keep Pequannock WQP
4P	Univeristy Hospital, 16 Bergen Street	2016-2018	7.33	29.44	Not measured	6.14	Keep Pequannock WQP
5P	Stephen Crane Village, 4 Steven Crane Plaza	2016-2018	7.61	32.96	Not measured	5.93	Keep Pequannock WQP
6P	City of Newark, 239 Central Avenue	2016-2018	7.41	30.54	Not measured	6.34	Keep Pequannock WQP
7P	Senior House 801 North 6th Street	2016-2018	7.38	29.49	Not measured	6.42	Keep Pequannock WQP
8P	Bradley Courts, 46N Munn Avenue	2016-2018	7.54	29.44	Not measured	6.14	Keep Pequannock WQP
9P	Columbus Hospital 495N 13th Street	2016-2018	7.30	29.67	Not measured	6.48	Keep Pequannock WQP
10P	Broadway House, 298 Broadway	2019 WQP Study	7.67	25.80	1.68	4.20	Change to Wanaque WQP
11P	Ivy Hill Liquors 521 Ivy Hill Plaza	2016-2018	7.65	30.89	Not measured	6.02	Keep Pequannock WQP
12P	Sanford Avenue Pharmacy, 1041 South Orange Avenue	2016-2018	7.42	32.39	Not measured	6.09	Keep Pequannock WQP
13P	Sub City, 81 Mount Vernon Place	2016-2018	7.50	31.11	Not measured	5.97	Keep Pequannock WQP

Table 3-4 - Wanaque WQP Sampling Locations Summary (July 2016 - December 2018; March-April 2019)

Sample ID	WQP Sampling Locations	Data Used	Wanaque				Comments
			pH average	Alkalinity (mg/L as CaCO ₃) average	Orthophosphate (PO ₄) average	Silica (mg/L as Silica) average	
BR	Belleville Reservoir	2016-2018	7.58	41.60	1.48	2.53	POE Wanaque
1W	Holiday Inn, 450 Route 1 & 9 South	2016-2018	7.81	40.38	1.41	2.66	Keep Wanaque WQP
2W	Newark City Hall, 930 Broad Street	2016-2018	7.42	32.41	0.09	5.72	Remove from WQP List - dual feeds to building
		Mar-Apr 2019	7.10	24.60	ND	5.93	
3W	Glamour's Salon, 251 Oliver Street	2016-2018	7.53	33.63	0.67	4.61	Keep Wanaque WQP
		Mar-Apr 2019	7.48	26.77	2.01	4.33	
4W	River Bank Auto Repairs, 638 Raymond Blvd	2016-2018	7.48	33.33	0.46	4.90	Keep Wanaque WQP
		Mar-Apr 2019	7.60	25.73	1.41	4.44	
5W	Hawkins School, 9 Hawkins Street	2016-2018	7.43	32.95	0.40	4.75	Keep Wanaque WQP
		Mar-Apr 2019	7.51	24.57	1.41	4.47	
6W	Seton Hall Law School, 1109 Raymond Blvd	2016-2018	7.59	32.34	0.45	5.01	Keep Wanaque WQP
		Mar-Apr 2019	7.53	25.50	1.38	4.42	
7W	Newark Health Service, 94 William Street	2016-2018	7.43	31.41	0.09	5.88	Keep Wanaque WQP
		Mar-Apr 2019	7.57	27.07	1.47	4.39	
8W	Firehouse, 360 Clinton Avenue	2016-2018	7.48	31.88	0.15	5.89	Change to Pequannock WQP - location
9W	Associated Humane Society, 124 Evergreen Avenue	2016-2018	7.60	40.42	0.76	3.26	Keep Wanaque WQP
10W	Rutgers University, 190 University Avenue	2016-2018	7.41	30.92	0.33	6.08	Keep Wanaque WQP
		Mar-Apr 2019	7.53	26.47	1.80	4.38	
11W	Senior Citizen Home, 9 Summit Street	2016-2018	7.42	30.74	0.04	5.96	Remove from WQP List - dual feeds to building
		Mar-Apr 2019	6.97	20.97	ND	6.78	
12W	Newark Library, 5 Washington Avenue	2016-2018	7.52	31.77	0.12	5.70	Keep Wanaque WQP
		Mar-Apr 2019	7.32	24.67	1.38	4.62	



Newark WQP Sampling Locations
Potential Influence from Pequannock on
Wanaque Water Quality

3.3 Chloride-to-Sulfate Mass Ratio

Galvanic corrosion on lead solder joints on copper plumbing can be affected by chloride concentrations, as indicated by the chloride to sulfate mass ratio (CSMR). CSMR is calculated by dividing the average chloride concentration by the average sulfate concentration (Nguyen, Stone, Clark, & Edwards, 2010). The literature reports a “threshold” CSMR value of 0.5, above which galvanic corrosion of lead solder on copper piping can increase. The greatest concerns, however, are utilities with lead solder joints that change their water chemistry to increase CSMR from below 0.5 to above 0.5 as indicated in the Water Research Foundation (WRF) 4088 Study (Nguyen, Stone, Clark, & Edwards, 2010).

The researchers in the WRF study observed that in waters with CSMR equal to or less than 0.5, very low corrosion rates were observed. High chloride relative to sulfate, yielding CSMRs above 0.5, tended to increase galvanic corrosion of lead solder connected to copper pipe. They also observed, statistically, that as relative concentrations of chloride to sulfate increased in the water supply, the 90th percentile lead concentration generally increased. In their bench-scale experiments, waters with high CSMR were consistently more aggressive in increasing lead leaching from solder galvanically connected to copper.

Historic chloride and sulfate data are not available for Newark’s Wanaque Gradient distribution system. However, chloride and sulfate data from the same water source are available just downstream of the Wanaque WTP. Chloride and sulfate concentrations are not expected to change substantially throughout a distribution system, so they would be expected to be similar within Newark’s Wanaque Gradient. Based on an average chloride concentration of 46.0 mg/L and an average sulfate concentration of 14.2 mg/L, Wanaque’s average CSMR is 3.2. Although Wanaque’s CSMR is above the 0.5 threshold, there are many systems that operate with similar or higher CSMRs that do not have high lead levels or AL exceedances. The likely reason for this is that much of the solder exposed to the water may have been released at very low rates over decades. The WRF research focused on simulating release of lead from solder that was abruptly subjected to high CSMR water. This is corroborated by full-scale experience where the CSMR changed abruptly due to a process or water quality change (e.g., systems changing from alum to PACl or alum to ferric chloride). In these cases, the “baseline” condition was a relatively low CSMR (however, often times greater than 0.5), and the operation change caused a sudden increase in CSMR, which contributed to lead release and spikes in tap water sampling results (Nguyen, Stone, Clark, & Edwards, 2010).

Data were obtained from 1993 to 2018 from NJDEP WaterWatch for PSWID NJ1613001, under TP003006, which represents the chloride and sulfate concentrations for a system downstream of the Wanaque WTP. The only data available for chloride and sulfate is one data point per year which is not sufficient to make a determination on whether or not the CSMR is increasing.

Based on discussions with the plant operators, no major treatment changes have been made in the last 20+ years that would impact chloride and sulfate concentrations.

Research and field experience indicate that orthophosphate can be effective in reducing lead release in conditions of galvanic corrosion, which is typically marked by a combination of low pH

and high CSMR at the solder surface (Nguyen, Stone, Clark, & Edwards, 2010)). The Wanaque Gradient is already dosing zinc orthophosphate in the drinking water.

Section 4

Sequential Sampling

The City of Newark conducted sequential sampling at seven locations in the Wanaque Gradient in December 2018, January 2019, April 2019 and May 2019. The purpose of this effort was to compare the Wanaque Gradient with the sequential sampling previously performed in the Pequannock Gradient. In addition, the sampling was conducted to evaluate potential sources of lead that may exist within the service line and premise plumbing from the service connection in the street to the drinking water tap in the house. Sequential sampling is an additional tool to assist in developing an understanding of the system as part of the CCT optimization. The sources of lead at the tap measured in sequential samples include lead service lines, lead-based materials contained in the premise piping (e.g., leaded solder, brass/bronze fittings, galvanized piping) and faucets.

4.1 Sequential Sampling Program Protocol

The sequential sampling program consisted of collecting the full volume of water between the kitchen faucet and the water main in small increments allowing for the isolation of water from various plumbing components, such as, but not limited to, fixtures, valves, pipe materials and meters. A memorandum dated September 10, 2018 by CDM Smith titled “Sequential Sampling Program Protocol for Tracking Lead in Drinking Water” provided the protocol for performing the sequential sampling.

In general, the sequential sampling process consisted of the following:

1. **Site Audit** - An initial visit to each home was conducted to document the cold-water piping, beginning at the faucet and traced back towards the water main in the street. This was used to calculate the volume in the water service line and determine the number and timing of samples needed for collection.
2. **Sample Collection and Analysis** - Sequential sampling is conducted after a stagnation period, between 6 to 12 hours, per the Lead and Copper Rule requirements. A 10-minute flush is conducted, without removing the faucet aerators, unless otherwise noted, prior to the stagnation period. Samples are taken at the kitchen sink in increments of 500 mL, or as determined by the site audit. A flushed sample is also taken at the end of the sequential program to test the water in the main. The faucet aerator was typically not removed for the flushing, with an exception described later in this section. The aerator was generally removed for sampling, depending on its accessibility. Samples were analyzed for the following information:
 - *pH (first sample, a middle sample, and flushed final sample measured in the field)*
 - *Temperature (first sample, a middle sample, and flushed final sample measured in the field)*

- *Free chlorine (first sample, a middle sample, and flushed final sample measured in the field)*
 - *Total Lead*
 - *Dissolved Lead*
 - *Total Copper*
 - *Silica Residual (SiO₂) (first sample, a middle sample, and flushed final sample)*
 - *Orthophosphate (mg/L as P) (first sample, a middle sample, and flushed final sample)*
 - *Alkalinity (first sample, a middle sample, and flushed final sample)*
 - *Conductivity (first sample, a middle sample, and flushed final sample)*
3. **Data Evaluation** – Once the samples were analyzed, the profile was plotted with cumulative volume on the X-axis and lead results on the Y-axis. Specific plumbing components were located along the service volume axis and the plumbing components most contributing to high lead values were noted.
 4. **Monitoring** – If the CCT is modified, the sequential sampling program would be performed on a regular basis to ascertain the effectiveness of the new/modified CCT treatment.

4.2 Results of Sequential Sampling in the Wanaque Gradient

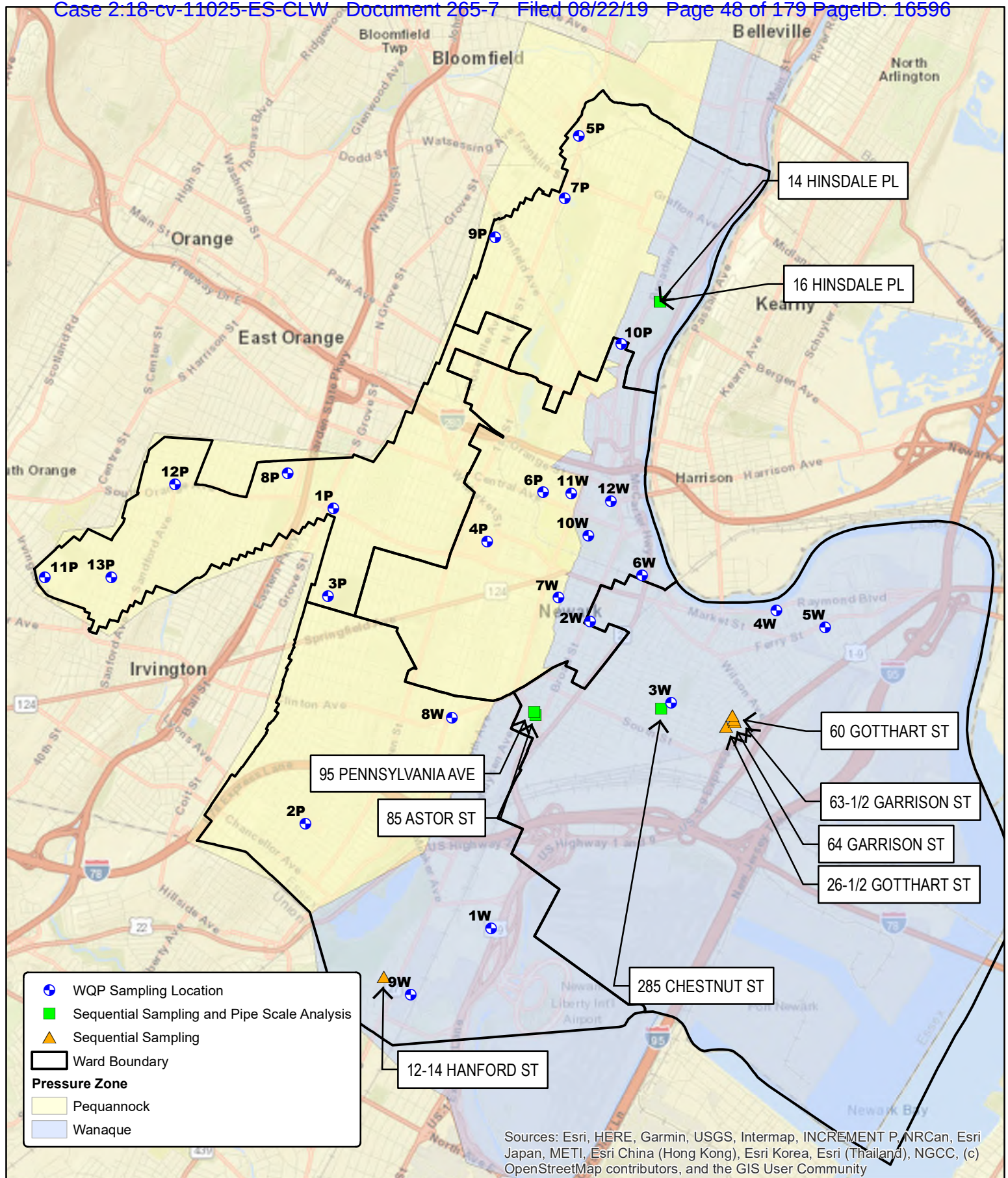
On December 14, 2018, CDM Smith coordinated sequential sampling for two residential locations in the Wanaque Gradient:

- 95 Pennsylvania Avenue (East Ward) (Also sampled post-LSL removal on January 19, 2019)
- 14 Hinsdale Place (North Ward) (Also sampled post-LSL removal on January 19, 2019)

The locations of these homes are shown in **Figure 4-1**. Sequential sampling was performed as described in Section 4.1 with the faucet aerator left on for flushing, but removed for sampling. Once the sequential sampling was complete, the lead service lines were replaced and portions of the service lines were sent to the EPA for scale analysis. On January 19, 2019, sequential sampling was again performed at these two residential locations, approximately 1 month after the lead service line had been replaced with copper. In the second sampling at each home, the aerator was removed prior to flushing and kept off for the duration of the sampling.

Additionally, sequential sampling was performed on January 11, 14, and 21, 2019 at the following addresses with LSLs:

- 26 ½ Gotthardt Street (East Ward)
- 285 Chestnut Street (East Ward)



Sequential Sampling and Scale Analysis Locations in Wanaque

Figure 4-1

- 64 Garrison Street (East Ward)
- 63 ½ Garrison Street (East Ward)
- 16 Hinsdale Place (North Ward)

Lastly, sequential sampling was performed at the following locations to address the remaining actions required by DEP, dated April 18, 2019. These locations have LSLs and were sampled on April 16 and May 17, 2019.

- 85 Astor Street (East Ward)
- 12-14 Hanford Street (South Ward)
- 60 Gotthardt Street (East Ward)

Upon review of the results for the Wanaque sequential sampling in February 2019, it was discussed with DEP that the following would be implemented when conducting the sequential sampling in April and May of 2019:

- Smaller aliquots of samples would be collected for the first liter to assist in pinpointing more specific components of the plumbing that may have elevated lead levels
- Dissolved lead would not be analyzed
- Implementation of additional quality control processes for field pH measurements

The locations of the ten (10) sequential sampling sites are shown on **Figure 4-1**. The faucet aerator was removed by Newark staff prior to the flushing process and remained off until sampling was completed for 95 Pennsylvania Avenue, 85 Astor Street, 12-14 Hanford Street, and 14 Hinsdale Place. The aerator was not confirmed to be removed by Newark staff for flushing for 64 Garrison Street, 63 ½ Garrison Street and 60 Gotthardt Street. The aerator was, however, removed during sampling. The aerator was fixed to the faucet fixture for, 285 Chestnut Street, 16 Hinsdale Place, and 26 ½ Gotthardt Street, and therefore was neither removed during the flushing process nor for sample collection.

The samples were analyzed for total lead (and sometimes soluble lead) and copper and the results are summarized by location in the subsections that follow. The background water quality was analyzed at the start of the testing (first sample or second sample), the middle of the testing (middle samples) and after a 10-minute flush (flushed sample).

For each location, lead is plotted against the cumulative water volume in a profile to identify lead contributions from different plumbing components and materials. The difference between the total lead and soluble lead, where tested, is insoluble or particulate lead. Particulate lead can be a result of scouring of deposits off the pipe wall disturbing the scale layers that have formed over time or from particulates collecting in the aerator or fixtures. Soluble lead is dissolved lead that has leached from the piping into the water. For each home's profile, the plumbing fixtures and materials are shown above the graph for correlation to the samples.

4.2.1 South Ward – 95 Pennsylvania Avenue (Previously East Ward)

The address 95 Pennsylvania Avenue is located in the South Ward. The mapping in **Figure 4-1** shows the address in the East Ward based on the previous ward boundaries. It was estimated that 95 Pennsylvania Avenue needed thirteen (13) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing and was sampled before the lead service line replacement (LSLR) and after the LSLR. A portion of the lead service line was sent to the EPA for a scale analysis. The following are the observations for the lead profile and water quality results for 95 Pennsylvania Avenue, as shown in **Tables 4-1** and **4-2** and **Figures 4-2** and **4-3**.

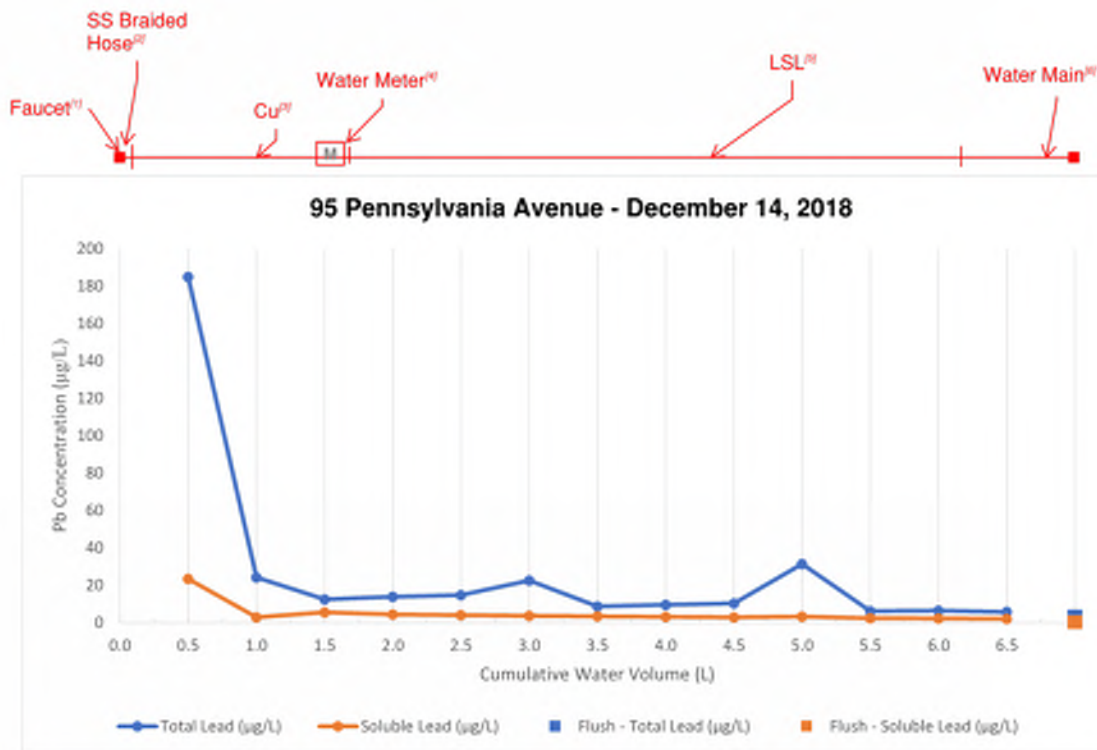
- The highest lead levels at this address were found in the interior plumbing components, including the faucet hosing. For the first sequential sampling, before the LSLR, soluble lead peaked at 23.4 µg/L and total lead at 185 µg/L in the first sample (on the faucet hosing and interior plumbing components). For the second sequential sampling (post-LSLR), soluble lead peaked at 19.8 µg/L in the 12th sample and the total lead peaked at 108 µg/L in the first sample. This appears to be all particulate lead and the homeowner should continue to flush without the aerator and replace the aerator.
- A spike in lead levels was seen in the 5th liter in the first sequential sampling (pre-LSLR) at 31.4 µg/L and in the 6th liter in the second sequential sampling (post-LSLR) at 38.3 µg/L. This could potentially be from a brass corp stop with lead or from a disturbance, possibly construction in the area.
- Significant particulate lead was found at this address in the first draw samples in both sequential sampling events. For the first sequential sampling, the aerator was removed on site prior to collecting samples but after flushing and stagnation. For the second sequential sampling, the aerator was removed prior to flushing and the stagnation period and remained off until sampling was completed.
- Silica concentrations were an average of 3.54 mg/L as SiO₂ for the first sequential sampling, which coincides with the Wanaque WQP ranges. Silica testing was not performed for the second sequential sampling.
- Orthophosphate measurements were an average of 1.45 mg/L as PO₄ for the first sequential sampling and 2.97 mg/L as PO₄ for the second sequential sampling, which coincides with the Wanaque WQPs measured in the distribution system. Note that the orthophosphate analysis for the first sequential sampling event was performed “out of hold,” or after the 48 hour required analysis time for a sample. It was performed within 72 hours of the sampling.
- Based on the water quality data collected at the tap, this location does not appear to have been significantly influenced by the Pequannock Gradient water at the time of the sampling events even though it is located on the border of the two gradients.
- The total copper in the first sequential sampling results ranged from ND to the maximum value of 0.239 mg/L (9th sample). For the second sequential sampling, the total copper results ranged from ND to the maximum value of 0.350 mg/L (12th sample).

Table 4-1 – Water Quality Analysis at 95 Pennsylvania Avenue

Date of Sampling	Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
Before LSLR (12/14/18)	First Liter	N/A			33.0	251.0	3.75	0.396 (1.19 mg/L as PO ₄)
	Middle Samples				31.0	252.0	3.64	0.503 (1.51 mg/L as PO ₄)
	Flushed Sample				23.0	248.0	3.24	0.546 (1.64 mg/L as PO ₄)
After LSLR (1/19/19)	First Liter	6.97	15.0	0.04	34.0	215.0	N/A	0.739 (2.22 mg/L as PO ₄)
	Middle Samples	6.99	12.8	0.06	31.0	244.0		0.686 (2.06 mg/L as PO ₄)
	Flushed Sample	7.07	8.1	0.56	25.0	243.0		1.54 (4.62 mg/L as PO ₄)

^[1]Values believed to be anomalous, see discussion section.**Table 4-2 – 95 Pennsylvania Avenue Lead Results**

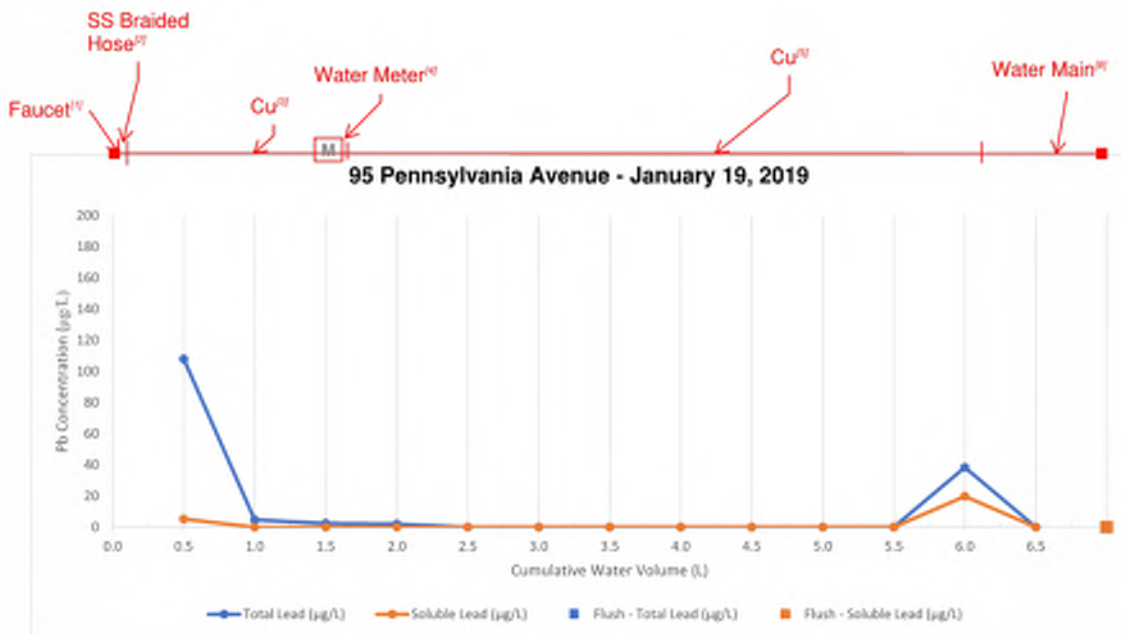
Sample ID	Before LSLR (12/14/2018)		After LSLR (01/19/2019)	
	Total Lead (µg/L)	Soluble Lead (µg/L)	Total Lead (µg/L)	Soluble Lead (µg/L)
1	185	23.4	108	5.24
2	24.2	2.86	4.75	< 2.0
3	12.5	5.52	2.40	< 2.0
4	13.8	4.41	2.06	< 2.0
5	14.7	4.00	< 2.0	< 2.0
6	22.6	3.63	< 2.0	< 2.0
7	8.68	3.37	< 2.0	< 2.0
8	9.53	3.07	< 2.0	< 2.0
9	10.3	2.94	< 2.0	< 2.0
10	31.4	3.31	< 2.0	< 2.0
11	6.14	2.38	< 2.0	< 2.0
12	6.43	2.21	38.3	19.8
13	5.74	2.04	< 2.0	< 2.0
Flushed	2.96	< 2.0	< 2.0	< 2.0



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-2 – 95 Pennsylvania Avenue Lead Profile – December 14, 2018



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] New Copper Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-3 – 95 Pennsylvania Avenue Lead Profile – January 19, 2019

- The pH measurements were an average of 7.01 in the sequential sampling event, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. pH measurement is seemingly simple, but in reality there are significant efforts beyond routine calibration required to obtain consistently accurate results. Electrodes can easily become scratched, deteriorated, or accumulate debris and require careful handling and storage. Subsequent testing of pH with 3 different electrodes at several locations found that one of three electrodes consistently produced significantly lower pH readings, while the remaining two electrodes provided pH readings within the range expected (7.0 to 7.7). As such, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.
- The flow rate was measured on site during the sampling. The first sampling event occurred using a flow rate of 0.51 gpm and the second sampling occurred using a flowrate of 0.45 gpm.
- After flushing the water at the faucet for 10 minutes, the soluble lead was non-detect (ND), and the total lead was 2.96 µg/L for the first sequential sampling. After the service line was replaced, both the soluble lead and total lead concentrations were ND in the flushed sample. As noted above, a spike in lead levels was seen in the 6th liter (or 12th sample). This may be the corp stop connection to the water main that was disturbed during the replacement. The homeowner should continue to flush the line after periods of stagnation. Newark can retest the 5th and 6th liter to confirm this is decreasing over time.

4.2.2 North Ward – 14 Hinsdale Place

It was estimated that 14 Hinsdale Place needed twenty (20) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder found on the copper indoor plumbing before the meter. This location was sampled before and after the LSLR. A portion of the lead service line was sent to the EPA for a scale analysis. The following are the observations for the lead profile results for 14 Hinsdale Place, as shown in **Tables 4-3 and 4-4** and **Figures 4-4 and 4-5**.

- The highest lead levels at this address were found in the interior plumbing components, including the faucet hosing and piping connected to the faucet. For the first sequential sampling, before the LSLR, the soluble lead peaked at 7.35 µg/L and total lead at 52.4 µg/L in the second sample (in the interior plumbing components after the faucet). For the second sequential sampling, after the LSLR, soluble lead peaked at 14.4 µg/L in the flushed sample and the total lead peaked at 17 µg/L in the fourth sample.
- Elevated amounts of particulate lead were found at this address the interior plumbing. For the first sequential sampling, the aerator was removed prior to collecting samples, but after flushing and stagnation. For the second sequential sampling, the aerator was removed prior to flushing and the stagnation period and remained off until sampling was completed.

Table 4-3 – Water Quality Analysis at 14 Hinsdale Place

Date of Sampling	Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
Before LSLR (12/14/18)	First Liter Sample	N/A			42.0	225.0	6.41	< 0.1 (< 0.3 mg/L as PO ₄)
	Middle Samples				28.0	210.0	6.48	< 0.1 (< 0.3 mg/L as PO ₄)
	Flushed Sample				28.0	214.0	6.57	< 0.1 (< 0.3 mg/L as PO ₄)
After LSLR (1/19/19)	First Liter Sample	6.76	15.1	0.06	27.0	214.0	N/A	< 0.1 (< 0.3 mg/L as PO ₄)
	Middle Samples	6.90	9.9	0.03	31.0	202.0		< 0.1 (< 0.3 mg/L as PO ₄)
	Flushed Sample	6.82	8.9	0.98	30.0	211.0		0.702 (2.11 mg/L as PO ₄)

^[1] Values believed to be anomalous, see discussion section.

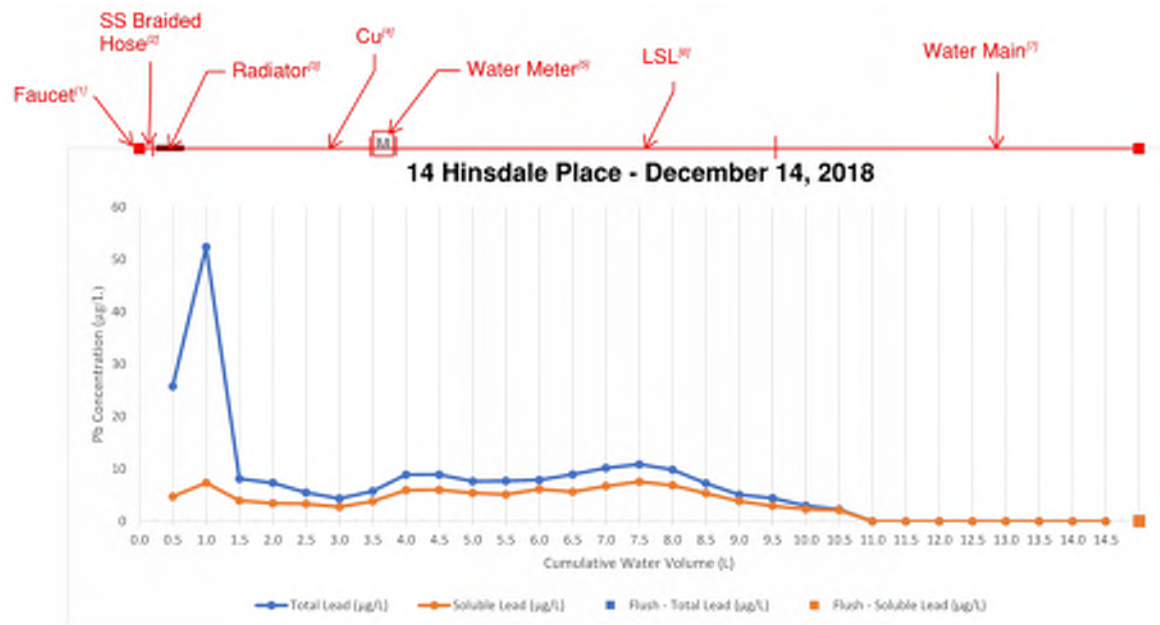
Table 4-4 – 14 Hinsdale Place Lead Results

Sample ID	Before LSLR (12/14/2018)		After LSLR (01/19/2019)	
	Total Lead (µg/L)	Soluble Lead (µg/L)	Total Lead (µg/L)	Soluble Lead (µg/L)
1	25.8	4.72	13.1	2.78
2	52.4	7.35	9.11	3.23
3	8.11	3.95	5.18	< 2.0
4	7.34	3.44	17.0	< 2.0
5	5.49	3.34	5.6	< 2.0
6	4.37	2.75	5.64	2.23
7	5.75	3.83	6.39	2.67
8	8.91	5.96	4.61	< 2.0
9	8.91	5.99	2.38	< 2.0
10	7.65	5.44	< 2.0	< 2.0
11	7.73	5.13	< 2.0	< 2.0
12	7.9	6.16	< 2.0	< 2.0
13	8.97	5.66	< 2.0	< 2.0
14	10.2	6.73	< 2.0	< 2.0
15	10.9	7.56	< 2.0	< 2.0
16	9.88	6.87	2.69	< 2.0
17	7.23	5.36	< 2.0	< 2.0
18	5.08	3.87	< 2.0	< 2.0

Section 4 • Sequential Sampling

Sample ID	Before LSLR (12/14/2018)		After LSLR (01/19/2019)	
	Total Lead (µg/L)	Soluble Lead (µg/L)	Total Lead (µg/L)	Soluble Lead (µg/L)
19	4.43	2.96	< 2.0	< 2.0
20	3.00	2.34	< 2.0	< 2.0
21	2.3	2.15	< 2.0	7.68 ^[1]
22	2.04	< 2.0	< 2.0	< 2.0
23	< 2.0	< 2.0	< 2.0	< 2.0
24	< 2.0	< 2.0	< 2.0	7.44 ^[1]
25	< 2.0	< 2.0	< 2.0	< 2.0
26	< 2.0	< 2.0	< 2.0	< 2.0
27	< 2.0	< 2.0	< 2.0	< 2.0
28	< 2.0	< 2.0	< 2.0	< 2.0
29	< 2.0	< 2.0	< 2.0	< 2.0
FLUSH	< 2.0	< 2.0	< 2.0	14.4 ^[1]

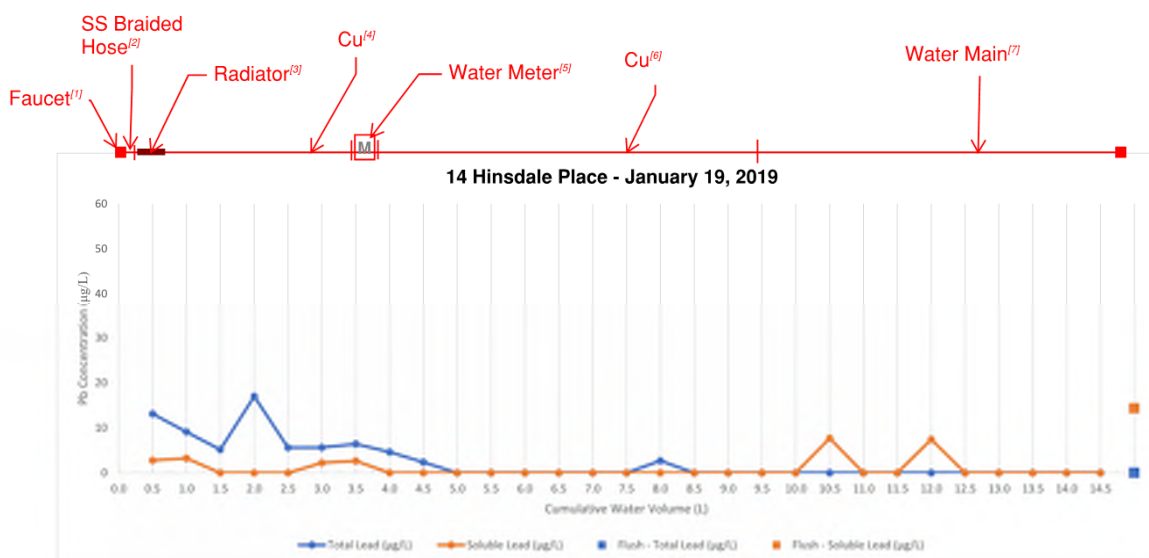
^[1] Original testing of samples resulted in soluble lead greater than total lead which is not plausible.



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Approximate Radiator Location Under Copper Pipe Segment, ^[4] Copper Pipe Segment, ^[5] Water Meter Location, ^[6] Lead Service Line Pipe Segment, ^[7] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-4 – 14 Hinsdale Place Lead Profile – December 14, 2018



[1] Kitchen Faucet Location, [2] Stainless Steel Braided Hose, [3] Approximate Radiator Location Under Copper Pipe Segment, [4] Copper Pipe Segment, [5] Water Meter Location, [6] New Copper Service Line Pipe Segment, [7] Water Main Location
 Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-5 – 14 Hinsdale Place Lead Profile – January 19, 2019

- Silica concentrations were an average of 6.45 mg/L as SiO₂ for the first sequential sampling, which does not coincide with the Wanaque WQPs measured at the Belleville Reservoir, but rather with the average WQPs for the Pequannock service area. The silica concentration was not tested during the second sequential sampling event.
- All orthophosphate results were less than 0.3 mg/L as PO₄ for the first sequential sampling. For the second sequential sampling event, the orthophosphate results were less than 0.3 mg/L as PO₄ in the internal plumbing samples and the orthophosphate level was 2.11 mg/L as PO₄ in the flushed sample. The interior plumbing orthophosphate results and the flushed sample in the first sequential sampling event do not coincide with the Wanaque WQPs measured in the distribution system indicating potential intermittent supplementation by the Pequannock water. Newark performed additional sampling at a hydrant on Hinsdale Place on January 30, 2019 which resulted in an orthophosphate level of 0.75 mg/L as PO₄. Note that the orthophosphate analysis was performed “out of hold,” or after the 48 hour required analysis time for a sample in the first sequential sampling event.
- Based on the water quality data collected at the tap, this location appears to have been influenced by the Pequannock Gradient water at the time of the sampling events.
- The total copper results for the first sequential sampling ranged from ND to the maximum value of 0.296 mg/L (2nd sample). For the second sequential sampling, the total copper results ranged from 0.11 mg/L to the maximum value of 1.65 mg/L (10th sample).

- The pH measurements averaged 6.82, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1 regarding pH probes, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.
- The flow rate was measured on site during the sampling. The first sampling event occurred using a flow rate of 0.64 gpm and the second sequential sampling had a flow rate of 1.60 gpm.
- The pH, temperature and chlorine residual were unable to be tested on site for the first sequential sampling. However, the temperature of the first 9 samples was fairly warm. During the site audit, a radiator was found to be located directly underneath a portion of the copper line in the basement. The radiator appears to be the source of the temperature increase and may have an impact on soluble and insoluble lead levels as warmer water increases lead levels in drinking water.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead results were ND in the first sequential sampling. After the service line was replaced, the soluble lead concentration was 14.1 µg/L and the total lead was ND in the flushed sample. The samples where the soluble lead is greater than the total lead are not plausible and are considered erroneous.

4.2.3 East Ward – 26 ½ Gotthardt Street

It was estimated that 26 ½ Gotthardt Street needed thirteen (13) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing before the meter. The following are the observations for the lead profile results for 26 ½ Gotthardt Street, as shown in **Tables 4-5** and **4-6** and **Figure 4-6**. It should be noted that some samples were re-tested for quality assurance. Both sample results, when applicable, are provided in **Table 4-6**.

Table 4-5 – Water Quality Analysis at 26 ½ Gotthardt Street

Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
First Liter	6.50	16.1	0.10	31.0	242.0	3.55	0.741 (2.22 mg/L as PO ₄)
Middle Samples	6.48	16.6	0.29	30.0	239.0	3.73	0.800 (2.40 mg/L as PO ₄)
Flushed Sample	6.62	16.0	0.62	30.0	241.0	3.64	0.749 (2.25 mg/L as PO ₄)

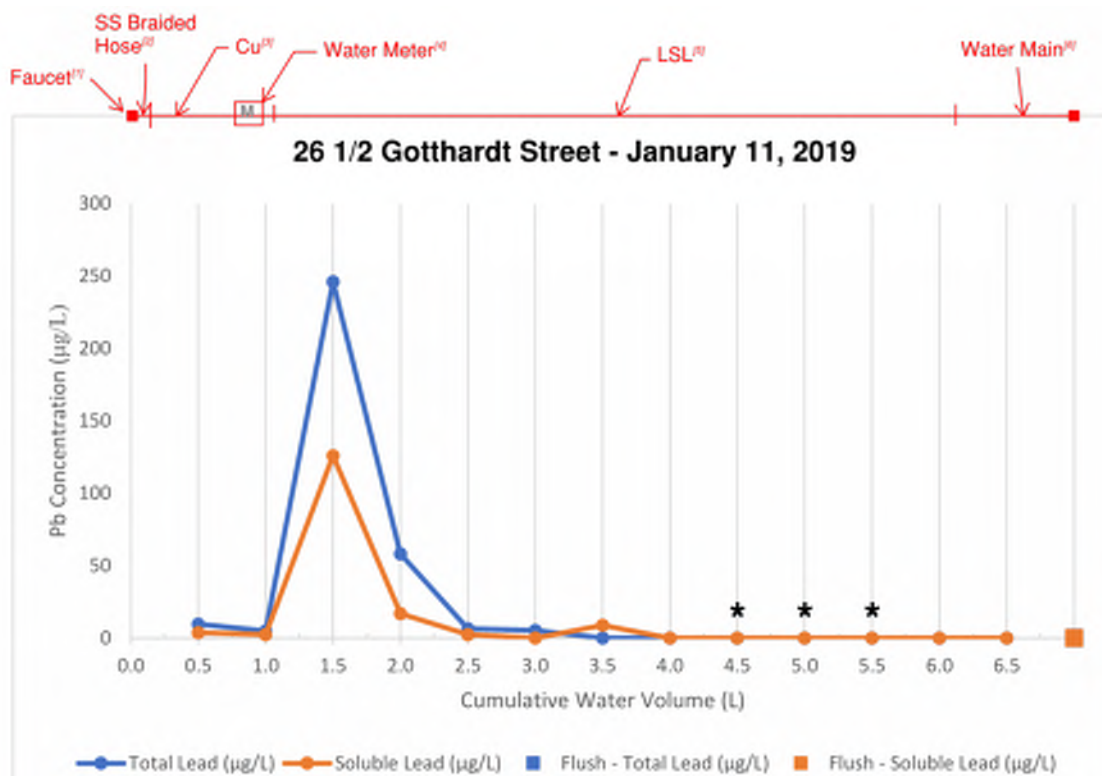
^[1] Values believed to be anomalous, see discussion section.

Table 4-6 – 26 ½ Gotthardt Street Lead Results

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	9.72	3.86
2	4.95	2.52
3	246	126
4	58.2	17
5	6.56	2.5
6	5.28	< 2.0
7	< 2.0	8.88 ^[2]
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0 (261) ^[1]
11	< 2.0	< 2.0 (4.03) ^[1]
12	< 2.0	< 2.0 (2.38) ^[1]
13	< 2.0	< 2.0
Flushed	< 2.0	< 2.0

^[1] Original testing of samples in parentheses (X) resulted in soluble lead greater than total lead which is not plausible. Samples retested.

^[2] Original testing of samples resulted in soluble lead greater than total lead which is not plausible.



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

*Result shown was from re-tested sample. Original result indicated soluble lead greater than total lead which is not plausible. Both results are provided in the table.

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-6 – 26 ½ Gotthardt Street Lead Profile – January 11, 2019

- The highest lead levels at this address were found in the interior plumbing components, including the faucet hosing and piping connected to the faucet. The aerator was connected to the faucet fixture and was unable to be removed for flushing and sampling. Soluble lead originally peaked at 261 µg/L in the 10th sample (which was shown to be greater than total lead), but after re-testing the sample it was determined to be ND. The updated results determined that the soluble lead peaked at 126 µg/L and total lead peaked at 246 µg/L in the third sample, which represents the copper piping before the meter through a portion of the lead service line and includes the water meter and brass fittings. The samples where the soluble lead is greater than the total lead are not plausible and are considered to be erroneous.
- Elevated particulate lead was found at this address in the third sample.
- Silica concentrations were an average of 3.64 mg/L as SiO₂, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.29 mg/L as PO₄, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to have been influenced by the Pequannock Gradient water at the time of sampling event.
- The total copper results ranged from ND to the maximum value of 0.224 mg/L (found in the 3rd sample).
- The pH measurements were an average of 6.53, which is lower than the WQPs measured in the Wanaque distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1 regarding pH probes, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.
- The flow rate was measured on site during the sampling and the samples were collected at a flow rate of 1.28 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

4.2.4 East Ward – 285 Chestnut Street

It was estimated that 285 Chestnut Street needed ten (10) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and there was no lead solder found on the copper indoor plumbing before the meter. A portion of the lead service line was sent to the EPA for a cross section scale analysis following the sequential sampling event. The following are the observations for the lead profile results for 285 Chestnut Street, as shown in **Tables 4-7** and **4-8** and **Figure 4-7**.

Table 4-7 – Water Quality Analysis at 285 Chestnut Street

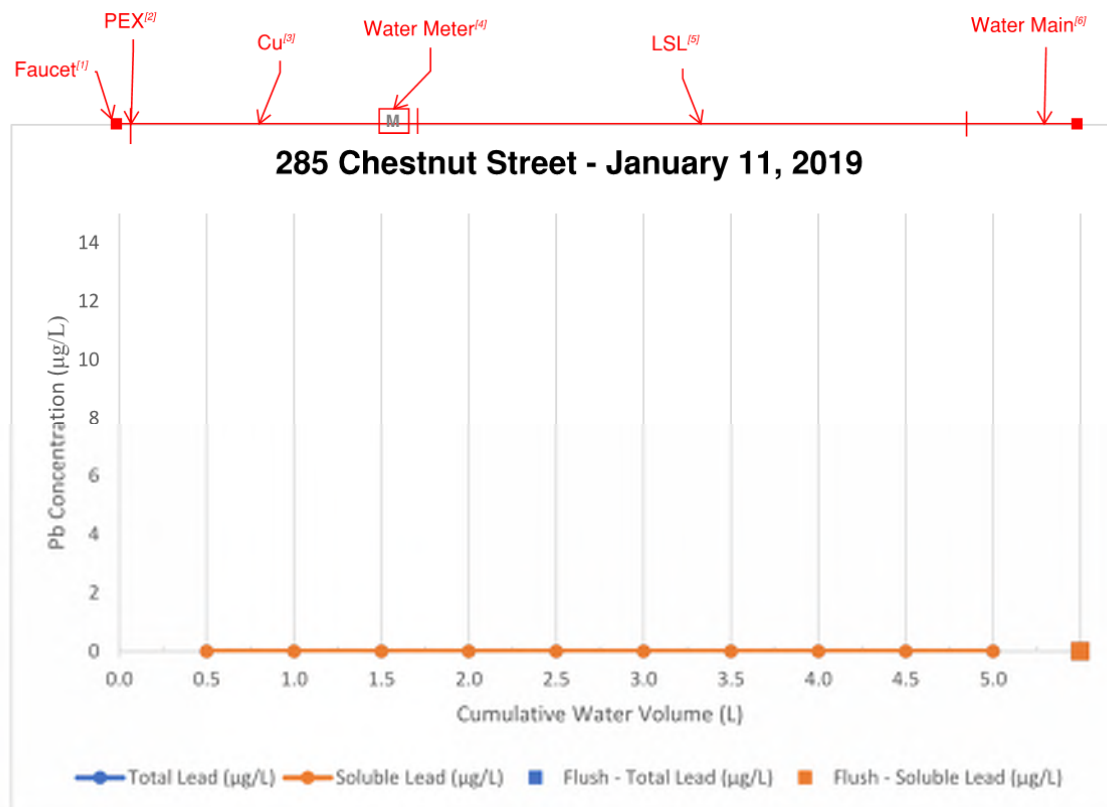
Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
First Liter	6.25	17.4	0.03	32.0	243.0	3.46	0.663 (1.99 mg/L as PO ₄)
Middle Samples	6.30	18.0	0.14	32.0	242.0	3.76	0.705 (2.16 mg/L as PO ₄)
Flushed Sample	6.36	20.0	0.36	31.0	240.0	3.75	0.700 (2.10 mg/L as PO ₄)

^[1] Values believed to be anomalous, see discussion section.

Table 4-8 – 285 Chestnut Street Lead Results

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	< 2.0	< 2.0
2	< 2.0	< 2.0
3	< 2.0	< 2.0
4	< 2.0	< 2.0
5	< 2.0	< 2.0
6	< 2.0	< 2.0
7	< 2.0	< 2.0
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0
Flushed	< 2.0	< 2.0

- There was no lead detected in any of the samples at this address.
- The aerator was connected to the faucet fixture and was unable to be removed for flushing and sampling.
- Silica concentrations were an average of 3.70 mg/L as SiO₂, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.08 mg/L as PO₄, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to have been influenced by the Pequannock Gradient water at the time of the sampling event.
- The total copper results were ND for all samples.



^[1] Kitchen Faucet Location, ^[2] Cross-Linked Polyethylene Pipe Segment, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-7 – 285 Chestnut Street Lead Profile – January 11, 2019

- The pH measurements were an average of 6.30, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1 regarding pH probes, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.
- The flow rate was measure on site during the sampling and the samples were collected at a flow rate of 0.98 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

4.2.5 East Ward – 64 Garrison Street

It was estimated that 64 Garrison Street needed twenty (20) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing before the meter. The following are the observations for the lead profile results for 64 Garrison Street, as shown in **Tables 4-9** and **4-10** and **Figure 4-8**. It should be noted that some samples were re-tested by the laboratory for quality assurance. Both sample results, when applicable, are provided in **Table 4-10**.

Table 4-9 – Water Quality Analysis at 64 Garrison Street

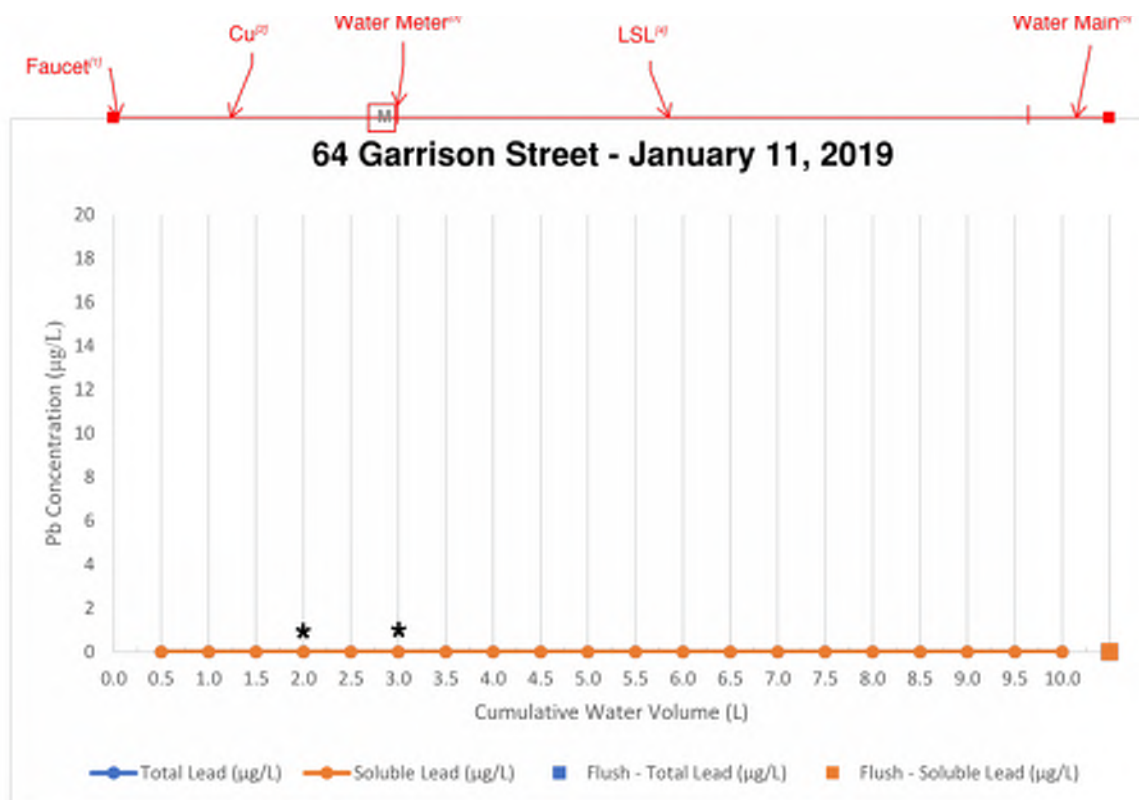
Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
First Liter	6.53	19.1	0.21	30.0	242.0	3.90	0.710 (2.13 mg/L as PO ₄)
Middle Samples	6.31	18.8	0.35	30.0	238.0	3.80	0.714 (2.14 mg/L as PO ₄)
Flushed Sample	6.30	18.2	0.53	30.0	233.0	3.72	0.715 (2.15 mg/L as PO ₄)

^[1] Values believed to be anomalous, see discussion section.

Table 4-10 – 64 Garrison Street Lead Results

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	< 2.0	< 2.0
2	< 2.0	< 2.0
3	< 2.0	< 2.0
4	< 2.0 (5.62) ^[1]	< 2.0 (17.9) ^[1]
5	< 2.0	< 2.0
6	< 2.0	< 2.0 (4.84) ^[1]
7	< 2.0	< 2.0
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0
11	< 2.0	< 2.0
12	< 2.0	< 2.0
13	< 2.0	< 2.0
14	< 2.0	< 2.0
15	< 2.0	< 2.0
16	< 2.0	< 2.0
17	< 2.0	< 2.0
18	< 2.0	< 2.0
19	< 2.0	< 2.0
20	< 2.0	< 2.0
Flushed	< 2.0	< 2.0

^[1] Original testing of samples in parentheses (X) resulted in soluble lead greater than total lead which is not plausible. Samples retested.



^[1] Kitchen Faucet Location, ^[2] Copper Pipe Segment, ^[3] Water Meter Location, ^[4] Lead Service Line Pipe Segment, ^[5] Water Main Location

*Result shown was from re-tested sample. Original result indicated soluble lead greater than total lead which is not plausible. Both results are provided in the table.

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-8 – 64 Garrison Street Lead Profile – January 11, 2019

- There was no lead detected in any of the samples at this address. Originally, the highest lead levels at this address were found in the interior plumbing components, including the faucet and piping connected to the faucet. Soluble lead originally peaked at 17.9 µg/L and total lead peaked at 5.62 µg/L in the fourth sample, which represents the copper line in the premise plumbing. It is not possible for soluble lead to be greater than total lead, and as such, the samples were reanalyzed. After re-testing, the amount of lead was found to be ND in all samples.
- The aerator was removed before collecting samples.
- Silica concentrations were an average of 3.80 mg/L as SiO₂, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.14 mg/L as PO₄, which coincides with the Wanaque WQP ranges.

- Based on the water quality data collected at the tap, this location does not appear to have been influenced by the Pequannock Gradient water at the time of the sampling event.
- The total copper results were ND for all samples.
- The pH measurements were an average of 6.39, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1 regarding pH probes, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.
- The flow rate was measure on site during the times of sampling and the samples were collected at a flow rate of 0.74 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

4.2.6 East Ward – 63 ½ Garrison Street

It was estimated that 63 ½ Garrison Street needed seventeen (17) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing before the meter. The following are the observations for the lead profile results for 63 ½ Garrison Street, as shown in **Tables 4-11** and **4-12** and **Figure 4-9**.

- The total lead peaked at 3.97 µg/L in the first sample, which represents the interior plumbing components, including the faucet hosing and piping connected to the faucet. There was no soluble lead detected in any of the samples at this address. The aerator was removed on site before collecting samples.
- There was a slight amount of particulate lead found in the sixth and seventh samples. These samples represent the lead service line located before the curb box.
- Silica concentrations were an average of 3.55 mg/L as SiO₂, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.15 mg/L as PO₄, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to have been influenced by the Pequannock Gradient water at the time of the sampling events.
- The total copper results ranged from ND to the maximum value of 0.0501 mg/L (first sample).

Table 4-11 – Water Quality Analysis at 63 ½ Garrison St.

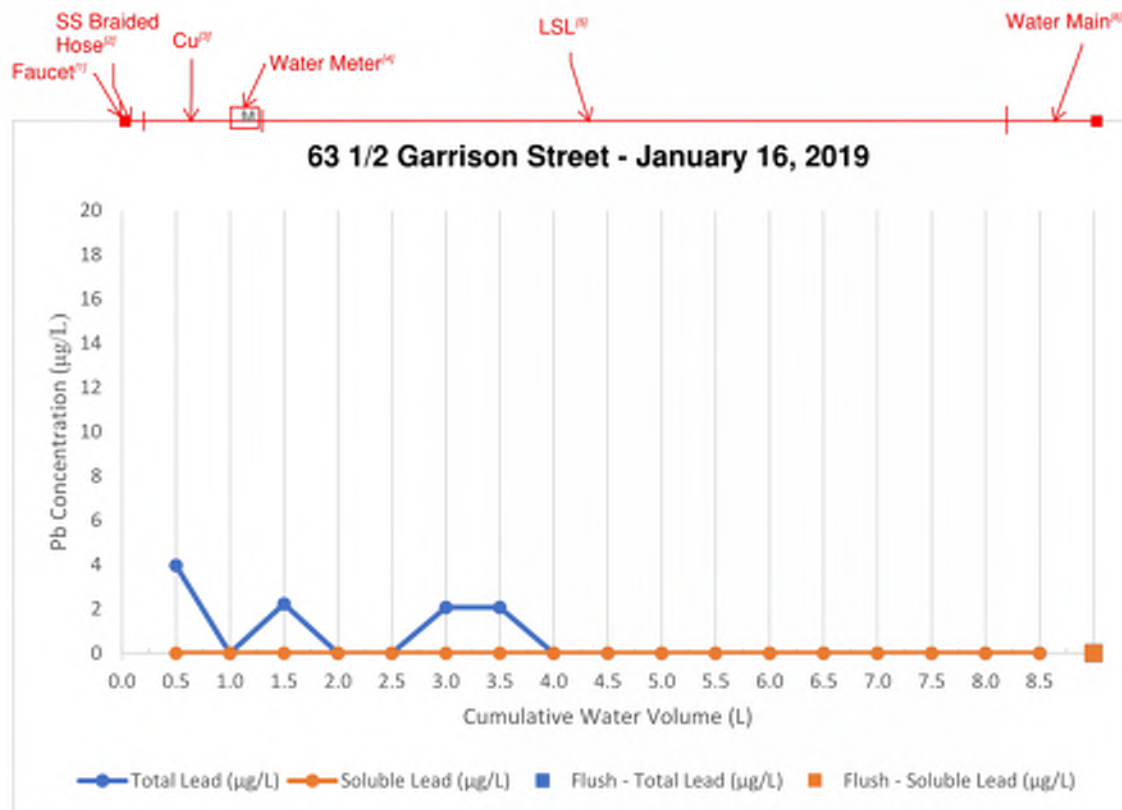
Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
First Liter	6.62	20.3	0.16	36.0	234.0	3.86	0.708 (2.12 mg/L as PO ₄)
Middle Samples	6.56	18.5	0.65	32.0	232.0	3.63	0.718 (2.15 mg/L as PO ₄)
Flushed Sample	6.61	15.7	0.69	29.0	210.0	3.15	0.728 (2.18 mg/L as PO ₄)

^[1] Values believed to be anomalous, see discussion section.**Table 4-12 – 63 ½ Garrison St. Lead Results**

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	3.97	< 2.0
2	< 2.0	< 2.0
3	2.23	< 2.0
4	< 2.0	< 2.0
5	< 2.0	< 2.0
6	2.07	< 2.0
7	2.07	< 2.0
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0
11	< 2.0	< 2.0
12	< 2.0	< 2.0
13	< 2.0	< 2.0
14	< 2.0	< 2.0
15	< 2.0	< 2.0
16	< 2.0	< 2.0
17	< 2.0	< 2.0
Flushed	< 2.0	< 2.0

- The pH measurements were an average of 6.60, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1 regarding pH probes, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.
- The flow rate was measured on site during the sampling and the samples were collected at a flow rate of 1.84 gpm.

- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-9 – 63 ½ Garrison St. Lead Profile – January 16, 2019

4.2.7 North Ward – 16 Hinsdale Place

It was estimated that 16 Hinsdale Place needed seventeen (17) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder on the copper indoor plumbing before the meter. A portion of the lead service line was sent to the EPA for a cross section scale analysis following the sequential sampling event. The following are the observations for the lead profile results for 16 Hinsdale Place, as shown in **Tables 4-13 and 4-14** and **Figure 4-9**.

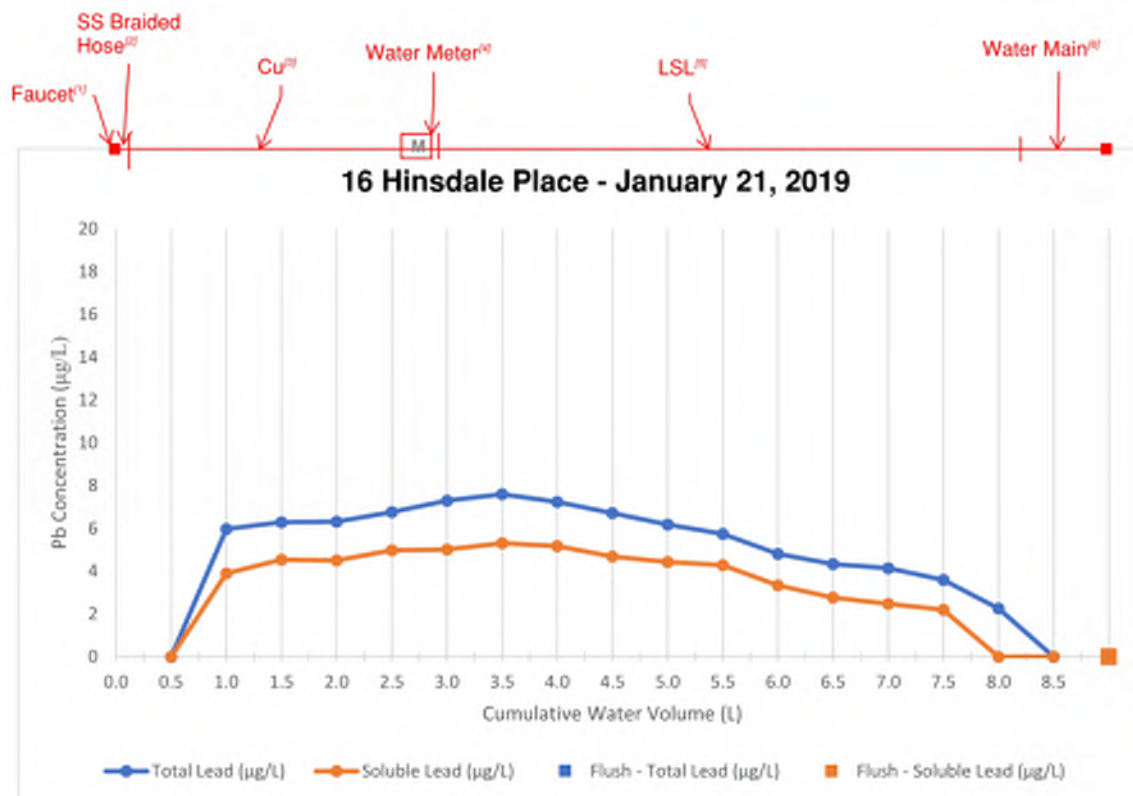
- The soluble lead at this address peaked at 5.31 µg/L and total lead peaked at 7.6 µg/L in the 7th sample, which represents where the copper piping transitions to the LSL and includes the meter and brass fittings.
- The aerator was connected to the faucet fixture and was unable to be removed for flushing and sampling.

Table 4-13 – Water Quality Analysis at 16 Hinsdale Place

Sample ID	pH ^[1]	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Conductivity (uMhos/cm)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
First Liter	6.60	13.2	0.19	29.0	197.0	N/A	< 0.1 (< 0.3 mg/L as PO ₄)
Middle Samples	6.62	11.1	0.62	27.0	201.0		< 0.1 (< 0.3 mg/L as PO ₄)
Flushed Sample	6.63	9.18	0.67	28.0	203.0		0.768 (2.30 mg/L as PO ₄)

^[1] Values believed to be anomalous, see discussion section.**Table 4-14 – 16 Hinsdale Place Lead Results**

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	< 2.0	< 2.0
2	5.97	3.9
3	6.29	4.54
4	6.32	4.51
5	6.76	4.98
6	7.3	5.01
7	7.6	5.31
8	7.24	5.17
9	6.71	4.69
10	6.18	4.43
11	5.74	4.28
12	4.81	3.34
13	4.33	2.77
14	4.14	2.48
15	3.59	2.2
16	2.26	< 2.0
17	< 2.0	< 2.0
Flushed	< 2.0	< 2.0



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-10 – 16 Hinsdale Pl. Lead Profile – January 21, 2019

- The orthophosphate measurements of the samples representing the interior plumbing were both less than 0.3 mg/L as PO₄, which does not coincide with the Wanaque WQPs measured in the distribution system and indicates potential supplementation by the Pequannock water. However, the flushed sample of orthophosphate resulted in a value of 2.30 mg/L as PO₄ which coincides with the Wanaque WQPs measured in the distribution system. Newark performed additional sampling at a hydrant on Hinsdale Place on January 30, 2019 which resulted in an orthophosphate level of 0.75 mg/L as PO₄.
- Based on the water quality data collected at the tap, this location appears to have been influenced by the Pequannock Gradient water at the time of the sampling events based on the orthophosphate sample results. With significantly higher orthophosphate residual in the flushed samples than the stagnated samples on Hinsdale Avenue, it is possible that the scales in this area currently have an orthophosphate demand.
- The total copper results ranged from 0.0161 mg/L up to the maximum value of 0.222 mg/L (first sample).
- The pH measurements were an average of 6.62, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are

significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1 regarding pH probes, it is suspected that the low pH readings found during the sequential sampling are not representative of actual conditions.

- The flow rate was measured on site during the times of sampling and occurred using a flow rate of 0.78 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead resulted as ND in the flushed sample.

4.2.8 South Ward – 85 Astor Street (Previously East Ward)

The address 85 Astor Street is located in the South Ward. The mapping in **Figure 4-1** shows the address in the East Ward based on the previous ward boundaries. It was estimated that 85 Astor Street needed (9) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main, in addition to collecting eight (8) 125 mL bottles to represent the first liter. This home had a lead service line and lead solder with copper and a segment of galvanized steel indoor plumbing. A portion of the lead service line was sent to the EPA for a scale analysis following the sequential sampling event. The following are the observations for the lead profile and water quality results for 85 Astor Street, as shown in **Tables 4-15, 4-16** and **4-17**, and **Figure 4-11**. It should be noted that laboratory analyses not performed in the field was performed by the EPA Region 2 laboratory for this site.

Table 4-15 – Water Quality Analysis at 85 Astor Street

Sample ID	pH	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
Second Liter	7.80	13.8	0.93	27.20	N/A	0.52 (1.56 mg/L as PO ₄)
Flushed Samples	7.78	13.6	0.89	24.60	N/A	0.52 (1.56 mg/L as PO ₄)

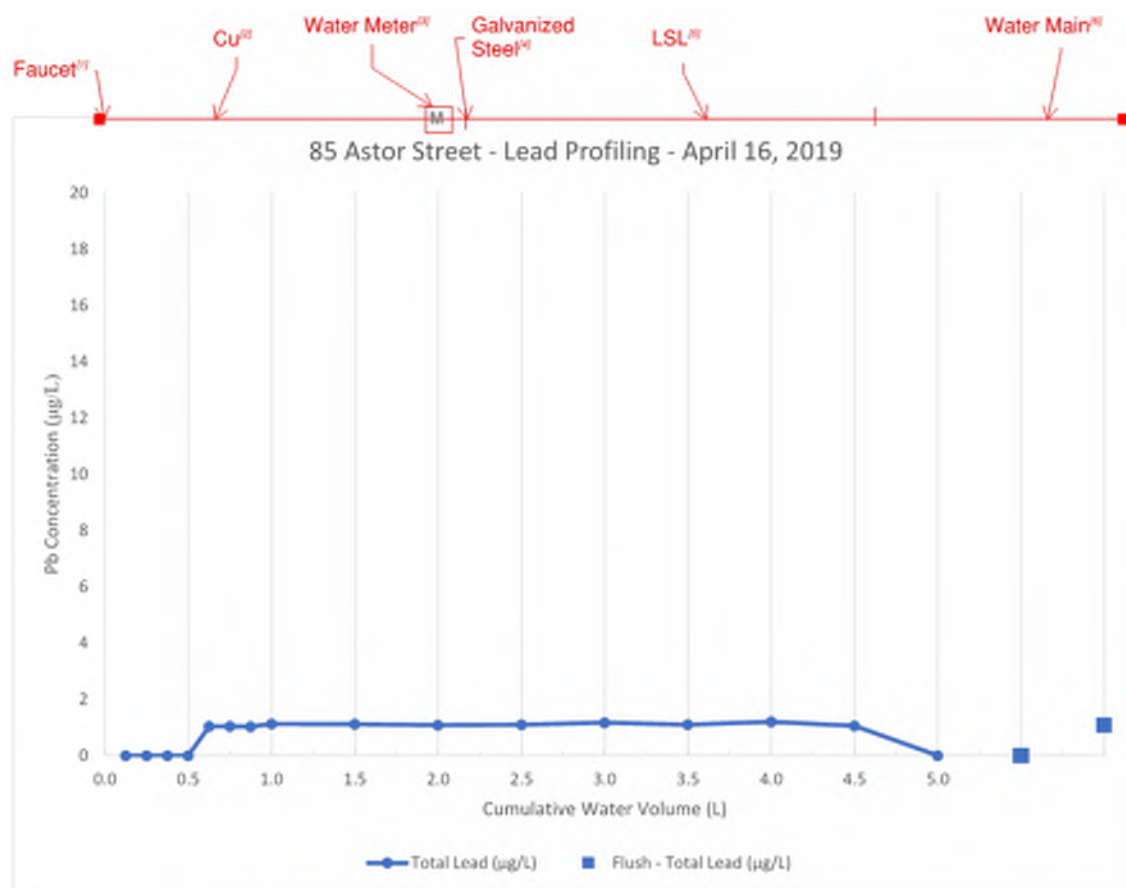
Table 4-16 – 85 Astor Street Lead Results

Sample ID	Total Lead (µg/L)
1	ND
2	ND
3	ND
4	ND
5	1.04
6	1.04
7	1.03
8	1.13
9	1.12
10	1.08

Sample ID	Total Lead (µg/L)
11	1.10
12	1.17
13	1.10
14	1.20
15	1.06
16	ND
Flushed	ND
Flushed	1.08

Table 4-17 – Flushed Water Quality Analysis at 85 Astor Street

Analyte	Result
Calcium (µg/L)	10700
Iron (µg/L)	0
Magnesium (µg/L)	2850
Potassium (µg/L)	818
Sodium (µg/L)	24500
Aluminum (µg/L)	45.1
Antimony (µg/L)	0
Arsenic (µg/L)	0
Barium (µg/L)	7.06
Beryllium (µg/L)	0
Cadmium (µg/L)	0
Chromium (µg/L)	0
Cobalt (µg/L)	0
Manganese (µg/L)	3.89
Molybdenum (µg/L)	0
Nickel (µg/L)	0
Selenium (µg/L)	0
Silver (µg/L)	0
Thallium (µg/L)	0
Vanadium (µg/L)	0
Zinc (µg/L)	2.81
Chloride (mg/L)	48
Fluoride (mg/L)	0
Sulfate (mg/L)	6.8



^[1] Kitchen Faucet Location, ^[2] Copper Pipe Segment, ^[3] Water Meter Location, ^[4] Galvanized Steel Pipe Segment, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-11 – 85 Astor Street Lead Profile – April 16, 2019

- The total lead at this address peaked at 1.20 µg/L in the 14th sample, which represents the lead service line piping right before the water main.
- The aerator was removed prior to sample collection.
- The silica concentrations are unavailable for this site.
- The orthophosphate measurement in the flushed sample was 1.56 mg/L as PO₄, which coincides with the Wanaque WQPs measured in the distribution system.
- Based on the water quality data collected, this location does not appear to have been influenced by the Pequannock Gradient water at the time of the sampling events, based on the orthophosphate results.
- The total copper results ranged from 1.67 mg/L up to the maximum value of 19.9 mg/L (first sample).

- The pH measurements were an average of 7.79, which is within the range of the Wanaque WQPs measured in the distribution system. pH readings were performed in the field.
- The flow rate was measured on site during the time of sampling and occurred using a flow rate of 0.91 gpm.
- After flushing the water at the faucet for 10 minutes, the total lead resulted as ND and 1.08 in the flushed samples.

4.2.9 South Ward – 12-14 Hanford Street

It was estimated that 12-14 Hanford Street needed nine (22) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main, in addition to collecting eight (8) 125 mL bottles to represent the first liter. This home had a lead service line and lead solder with copper indoor plumbing. The following are the observations for the lead profile and water quality results for 12-14 Hanford Street, as shown in **Tables 4-18, 4-19 and 4-20**, and **Figure 4-12**. It should be noted that laboratory analyses not performed in the field were performed by the EPA Region 2 laboratory for this site.

Table 4-18 – Water Quality Analysis at 12-14 Hanford Street

Sample ID	pH	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
Second Liter	7.94	19.0	0.44	26.6	N/A	0.615 (1.85 mg/L as PO ₄)
Flushed Samples	7.89	16.2	0.49	25.6	N/A	0.58 (1.75 mg/L as PO ₄)

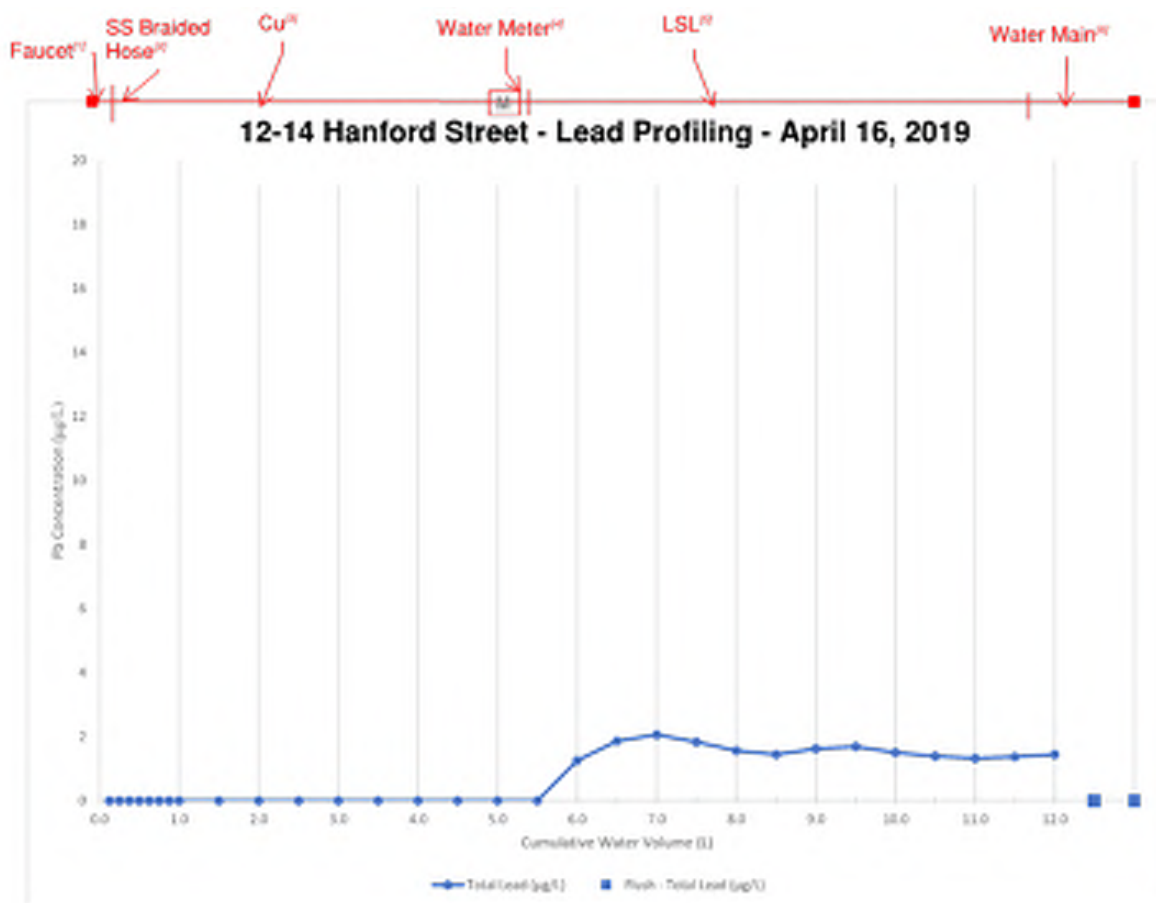
Table 4-19 – 12-14 Hanford Street Lead Results

Sample ID	Total Lead (µg/L)
1	ND
2	ND
3	ND
4	ND
5	ND
6	ND
7	ND
8	ND
9	ND
10	ND
11	ND
12	ND
13	ND
14	ND

Sample ID	Total Lead (µg/L)
15	ND
16	ND
17	ND
18	1.25
19	1.86
20	2.06
21	1.83
22	1.56
23	1.44
24	1.62
25	1.69
26	1.5
27	1.39
28	1.32
29	1.37
30	1.44
Flushed	ND
Flushed	ND

Table 4-20 – Flushed Water Quality Analysis at 12-14 Hanford Street

Analyte	Result
Calcium (µg/L)	10900
Iron (µg/L)	60.50
Magnesium (µg/L)	2880
Potassium (µg/L)	817
Sodium (µg/L)	24600
Aluminum (µg/L)	36.0
Barium (µg/L)	6.81
Manganese (µg/L)	3.13
Chloride (mg/L)	48.0
Fluoride (mg/L)	0.00
Sulfate (mg/L)	7.00



^[1] Kitchen Faucet Location, ^[2] Stainless Steel Braided Hose, ^[3] Copper Pipe Segment, ^[4] Water Meter Location, ^[5] Lead Service Line Pipe Segment, ^[6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-12 – 12-14 Hanford Street Lead Profile – April 16, 2019

- The total lead at this address peaked at 2.06 µg/L in the 14th sample, which represents the lead piping segment located after the water meter.
- The silica concentrations are unavailable for this site.
- The aerator was removed prior to sample collection.
- The orthophosphate measurement in the flushed sample was 1.75 mg/L as PO₄, which coincides with the Wanaque WQPs measured in the distribution system.
- Based on the water quality data collected, this location does not appear to have been influenced by the Pequannock Gradient water at the time of the sampling events, based on the orthophosphate results.

- The total copper results ranged from 4.4 mg/L up to the maximum value of 106 mg/L (third 125 mL sample).
- The pH measurements were an average of 7.92, which is within the range of the Wanaque WQPs measured in the distribution system. pH readings were performed in the field.
- The flow rate was measured on site during the time of sampling and occurred using a flow rate of 0.86 gpm.
- After flushing the water at the faucet for 10 minutes, the total lead resulted as ND in the flushed samples.

4.2.10 East Ward – 60 Gotthardt Street

It was estimated that 60 Gotthardt Street needed twelve (12) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main, in addition to collecting eight (8) 125 mL bottles to represent the first liter. This home had a lead service line and lead solder with copper and a segment of galvanized steel indoor plumbing. The following are the observations for the lead profile and water quality results for 60 Gotthardt Street, as shown in **Tables 4-21, 4-22 and 4-21**, and **Figure 4-13**. It should be noted that laboratory analyses not performed in the field were performed by the EPA Region 2 laboratory for this site.

Table 4-21 – Water Quality Analysis at 60 Gotthardt Street

Sample ID	pH	Temp (deg C)	Free Cl ₂ (mg/L)	Alkalinity (mg/L CaCO ₃)	Silica (mg/L SiO ₂)	Orthophosphate (as P)
Second Liter	7.8	25.4	0.43	27.20	4.54	0.547 (1.64 mg/L as PO ₄)
Flushed Samples	7.91	21.8	0.61	28.60	4.28	0.517 (1.55 mg/L as PO ₄)

Table 4-22 – 60 Gotthardt Street Lead Results

Sample ID	Total Lead (µg/L)
Q1	ND
Q2	ND
Q3	ND
Q4	ND
Q5	ND
Q6	ND
Q7	ND
Q8	ND
Q9	ND
Q10	ND
Q11	ND

Sample ID	Total Lead (µg/L)
Q12	ND
Q13	ND
Q14	ND
Q15	ND
Q16	ND
Q17	ND
Q18	ND
Q19	ND
Q20	ND
Q21 FLUSH	ND
Q22 FLUSH	Not Tested

Table 4-23 – Flushed Water Quality Analysis at 60 Gotthardt Street

Analyte	Result
Calcium (µg/L)	11600
Iron (µg/L)	0
Magnesium (µg/L)	2880
Potassium (µg/L)	818
Sodium (µg/L)	25400
Aluminum (µg/L)	31.8
Antimony (µg/L)	0
Arsenic (µg/L)	0
Barium (µg/L)	7.38
Beryllium (µg/L)	0
Cadmium (µg/L)	0
Chromium (µg/L)	0
Manganese (µg/L)	1.04
Nickel (µg/L)	0
Selenium (µg/L)	0
Silver (µg/L)	0
Thallium (µg/L)	0
Vanadium (µg/L)	0
Zinc (µg/L)	2.15
Calcium (µg/L)	11600
Iron (µg/L)	50.0
Chloride (mg/L)	46.0
Fluoride (mg/L)	0.05
Sulfate (mg/L)	6.30

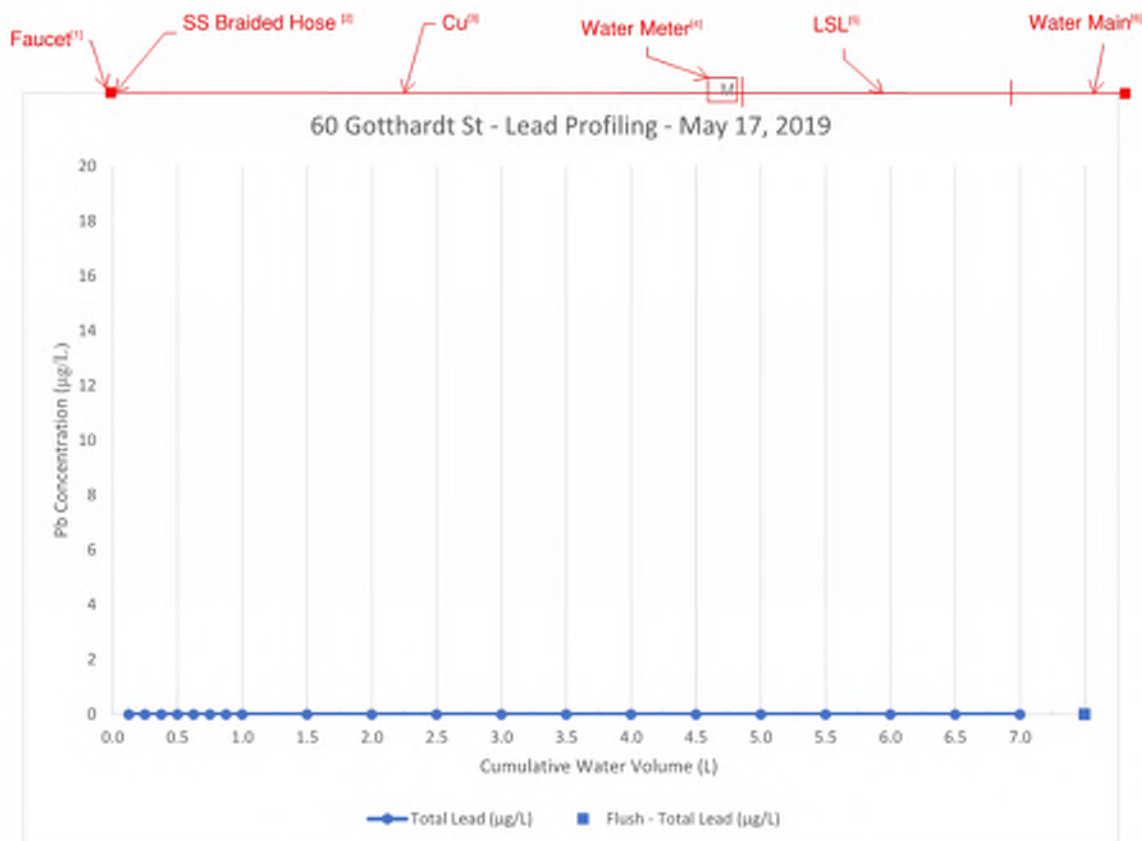


Figure 4-13 – 60 Gotthardt Street Lead Profile – May 17, 2019

- There was no lead detected in any of the samples at this address.
- The aerator was removed before collecting samples.
- Silica concentrations were an average of 4.41 mg/L as SiO₂, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 1.60 mg/L as PO₄, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to have been influenced by the Pequannock Gradient water at the time of the sampling event.
- The total copper results ranged from 3.85 to the maximum value of 54.8 mg/L (7th sample, located within the first liter).
- The pH measurements were an average of 7.86, which coincides with the Wanaque WQPs measured in the distribution system.

- The flow rate was measured on site during the sampling and the samples were collected at a flow rate of 0.46 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed samples.

4.3 Discussion

Lead sequential sampling was used in the Wanaque Gradient to compare with the previous sequential sampling performed in the Pequannock Gradient, to isolate the source(s) of lead in tap water in a given home, and to compare soluble and particulate lead as an indication of the stability of the protective scale. In addition, over time, lead sequential sampling can be used as a tool to monitor the effectiveness of CCT implementation or optimization.

It is important to recognize that both site specific and systemic factors may influence the lead levels measured at the water tap. Site specific factors include physical characteristics of the lead service line (length, diameter, surface area), water use patterns before and during sampling, piping configurations, hydraulic conditions, and manufacturing materials used for piping and fittings. Systemic factors include water quality, water pressure, scale formation and scale breakdown on the service line. These factors can contribute to variability in sampling results within the same water system and over time. At 95 Pennsylvania Avenue, 14 Hinsdale Place and 26 ½ Gotthardt Street, higher lead results were found in the interior plumbing or at the start of the lead service line during the sequential sampling. These results are consistent with other sequential sampling studies for systems with orthophosphate treatment that indicate peak lead concentrations often originate from the premise piping and/or the faucet, and not the lead service line where a stable orthophosphate scale may have formed.

4.3.1 Differences Between LCR Compliance Sampling and Sequential Sampling

There are several major differences between LCR compliance sampling (with a Lead AL established at 15 µg/L) and the sequential sampling protocols that may result in the detection of higher lead levels than LCR compliance sampling. Some of the major differences are provided in **Table 4-24**.

Table 4-24 – Key Differences Between LCR Compliance Sampling and Sequential Sampling Protocols

Sampling Characteristic	LCR Compliance Sampling Protocol	Sequential Sampling Protocol	Potential Impact to Lead Results
Sample Volume	First Liter (1,000 mL)	125 mL, 250 mL or 500 mL samples for the first liter and 500 mL samples throughout the remainder of entire service	Smaller volumes collected using the sequential sampling protocol can better identify the location of the source of the lead and can result in a higher value without dilution from a larger sample.

Section 4 • Sequential Sampling

Sampling Characteristic	LCR Compliance Sampling Protocol	Sequential Sampling Protocol	Potential Impact to Lead Results
Stagnation Period	Minimum 6 hours stagnation	6-12 hours of stagnation	A stagnation period greater than 6 hours may increase soluble lead results with changing water quality and water may becoming more aggressive as it stagnates.
Removing the Aerator	Not removed during stagnation or sampling	Removed during sampling (when applicable)	Removing the aerator may increase the reported value of particulate lead because there is no screen to filter the particulates out of the water.
Flushing Before Stagnation Period	No flushing	Flushing before the stagnation period	Flushing before the stagnation period can stimulate migration of particulate lead that has settled throughout the plumbing which may result in higher particulate lead results in sequential sampling.
Sampling Flow Rate	Sampling flow rate should be similar to the flow rate used to fill a glass of water.	Sampling flow rate averaged approximately 1 gpm. This may be slightly higher than the LCR compliance sampling flow rate.	A higher flow rate may disturb settled particulate lead in the home plumbing and show up in the samples.
Sampling Conducted by	Homeowner	Laboratory technician	Sampling protocol procedures are more consistent for multiple sampling sites when one person (i.e. laboratory technician) is taking samples.

Varying lead results are not uncommon when comparing sequential sampling and LCR compliance sampling for systems that are in compliance with the LCR (i.e. 90th percentile of first liter samples below 15 µg/L). As an example, field studies using the sequential sampling method were conducted at drinking water taps in Seattle Public Schools. Results showed elevated lead levels in the first and second samples drawn, which indicated a release of lead likely originating from the water fountain bubbler head or associated fittings and components (Boyd , Pierson, Kirmeyer, Britton, & English, 2006). These sample locations indicated lead results greater than the LCR Lead AL in the sequential sampling testing; however, Seattle has met LCR requirements in their distribution system since 2003.

4.3.2 Samples with Soluble Lead Greater Than Total Lead

Soluble lead is tested by filtering out particulate lead from total lead samples. Both soluble lead samples and the total lead samples are acidified prior to testing. The acidification is done in soluble lead samples after the sample is filtered. Soluble lead and particulate lead should theoretically equal total lead.

A few samples in the sequential sampling process were initially reported by the laboratory to have soluble lead greater than total lead. This is clearly inaccurate. Most of the results in Section 4 that indicated soluble lead greater than total lead were retested. The samples that have been retested resulted in soluble lead less than total lead, as expected. Therefore, the samples that were retested were used in the analysis. The original sample values are shown on the tables only for information.

Although lead sampling does have a margin of error, some results indicated significant variations. The laboratory has been requested to provide an explanation for the variability in the results.

4.3.3 Potential Causes of Lead Levels in Premise Plumbing

Lead was a component in solder on copper piping on interior, or premise, plumbing until it was banned in 1986. Brass components also contained significant lead content until 1986 when up to 8-percent of lead (by weight) was allowed to be classified as “lead-free”. In 2014, the “lead-free” limit was changed to 0.25-percent by weight by the EPA.

Lead results in premise plumbing after a stagnation period can be greater than lead results in a lead service line when the scale on a lead service line is stable and galvanic reactions between metals (i.e. lead solder and copper piping) or lead in brass fittings dominate the lead profile.

The smaller sampling volume utilized during sequential sampling can provide a better estimate of the source of lead levels in premise plumbing and the contribution of that source to the lead levels detected. Levels of lead that are found in the first few samples taken during sequential sampling may not be representative of the levels of lead seen from the one (1) liter sample required during LCR compliance testing.

The following factors may contribute to elevated levels of lead found in the first two (2) liters of sampling in the Wanaque Gradient samples:

- **Brass components in the premise plumbing or inline service line components.** While plumbing suppliers have now developed fixtures and other plumbing system components that contain no or low levels of lead, many homes in the Wanaque Gradient were constructed prior to 1986 and likely have premise plumbing components that contain brass with lead. Brass materials are known to cause “dezincification”. When dezincification occurs, zinc is released from the brass or alloyed material and the remaining lead and copper can react in water by galvanic corrosion, thus allowing further release of lead into the water (Boyd, Pierson, Kirmeyer, Britton, & English, 2006). Brass ferrules, which often contain lead, are often found inside the stainless steel threaded hose connectors that attach the stainless steel braided hose under the sink to the faucet.

- **Faucets and immediate connective piping containing lead.** Faucets and immediate connective piping can provide a significant contribution of lead. The literature reports that faucets and immediate connective piping can contribute 5 to 31 percent of the lead in the first liter sample collected at the tap for LCR compliance testing (Sandvig, et al., 2008). In the case of faucets, variability in configuration and manufacturing can produce variations in lead content. Older faucets or decorative faucets can have higher lead content.
- **Flushing prior to the stagnation period during sequential sampling.** LCR sampling does not require flushing prior to collecting one-liter sample. At sites with lead service lines, fully flushed samples, such as in the sequential sampling, may contain measurable lead due to uptake of particulate lead as the water flows through the system to the tap. Therefore, measurable lead may be present in the background water at the start of the stagnation period for LCR sampling, further elevating lead levels after stagnation (Sandvig, et al., 2008).
- **Particulate lead in the aerator.** Because most of the samples in the sequential sampling were taken with the aerator off, particulate lead that may typically be screened was free to flow into the samples. This can be prevented by regularly cleaning aerators and flushing prior to using the water for drinking or cooking.
- **Inconsistent orthophosphate in the Wanaque Gradient.** It is believed that the zinc orthophosphate from NJDWSC is consistently supplied at an approximately 1.5 to 1.8 mg/L as PO₄ dose. Additional sampling is currently being performed to determine if the orthophosphate has been diluted from the Pequannock water.
- **Wanaque water supplemented by Pequannock water.** As discussed in Section 3.2.1, water from the Pequannock Gradient can enter the Wanaque Gradient through manual division gate valves and through automatic pressure regulating valves. Several areas were identified within the Wanaque Gradient that appear to have experienced diluted orthophosphate residuals and higher silica concentrations, indicating that they were likely influenced by the Pequannock Gradient. Since January 2019, all division gates were closed and orthophosphate levels have increased in the Wanaque Gradient both in the sequential samples and in the WQP samples.

4.3.4 Comparison of Pequannock and Wanaque Sequential Sampling Results

In comparing only the highest lead concentration in the sequential sampling profiles, one would compare the results at some sites in the Wanaque Gradient (95 Pennsylvania Avenue and 26 ½ Gotthardt Street) to the sequential sampling performed in the Pequannock Gradient at 674 5th Street in Newark, which had a peak lead value of 147 µg/L as presented in the Pequannock OCCT report. However, the major difference between the samples taken in the Wanaque Gradient and the samples taken in the Pequannock Gradient is that the Wanaque Gradient profiles consistently result in non-detect lead levels for the majority of the lead service line and for the flushed samples. The profiles performed in the Pequannock Gradient did not result in non-detect lead levels, even in the flushed samples from the water mains that do not contain lead. It was determined in that study that the scales on the lead service lines for those receiving Pequannock water are unstable, and therefore, water passing through the lead service lines is carrying

particulate lead from the unstable scales and soluble lead from direct contact with the lead pipes to the tap. This was confirmed through the scale analyses performed by the EPA. As a result, flushing the service line, as generally recommended by the literature in reducing lead levels in drinking water, was deemed ineffective at reducing lead concentrations in the Pequannock Gradient. Based on the sequential sampling alone, it appears that flushing is an effective method in the Wanaque Gradient to reduce lead concentrations at the tap, and the corrosion control treatment provides protection for residents. The nature of the pipe scales is discussed further in Section 5.

Section 5

Scale Analysis

In December 2018 and February, March, and May 2019, Newark sent five (5) lead service pipe segments from where sequential sampling was conducted in December, January, April and May of 2019 to the EPA Advanced Materials and Solids Analysis Research Core in Cincinnati, OH for analysis. The lead service lines were removed from the following selected locations, see Section 4 for reference:

- 95 Pennsylvania Avenue (East Ward)
- 14 Hinsdale Place (North Ward)
- 285 Chestnut Street (East Ward)
- 16 Hinsdale Place (North Ward)
- 85 Astor Street (East Ward)

The locations listed above are shown on the map in **Figure 4-1**. This section presents the results of the analyses that EPA performed on the pipe scales.

Analysis of scales from pipes that reflect actual distribution system conditions provides a direct indication of the effectiveness of a current treatment process to control lead release. Knowledge of the characteristics and behavior of the lead solids that have been formed on the pipe walls can be integrated with water quality and operational information to understand mechanisms of corrosion inhibition, speciation of metals, and predictions of lead mobility/stability, and can assist in implementation of corrective treatment changes. Knowing how a contaminant is chemically associated in distribution system scale materials can help with estimating the probability of unintended adverse consequences of treatment or water quality changes.

5.1 EPA Scale Analysis Testing and Results

The EPA conducted the following tests on the three lead pipes:

- X-ray diffraction (XRD) analysis – identifies crystalline mineral compounds
- Scanning electron microscopy (SEM)/Energy dispersive spectroscopy (EDS) elemental mapping – identifies general areas where different elements exist within the scale

The testing evaluated the scales in different layers on the pipe wall, which can indicate the history of water chemistry impacts over time. The technique involves separating each solid phase layer for analysis, from the outermost layer (the layer in direct contact with the flowing water) to the innermost layer (the layer directly against the lead pipe wall).

The EPA results for 95 Pennsylvania Avenue, 14 Hinsdale Place were provided on February 14, 2018 and on June 19, 2019 for 285 Chestnut Street, 16 Hinsdale Place and 85 Astor Street. .

Section 5 • Scale Analysis

Figures 5-1 through 5-5 show images of the pipe scales in cross section for each of the three sites. The compilation of the EPA analysis is included as **Appendix A**. A summary of the compounds found at each location from the outermost layer in contact with the flowing water (L1) to the innermost layer adjacent to the pipe wall (highest “L”) is provided in **Table 5-1**. The “+” indicates the relative presence of a compound in the scale analyzed.

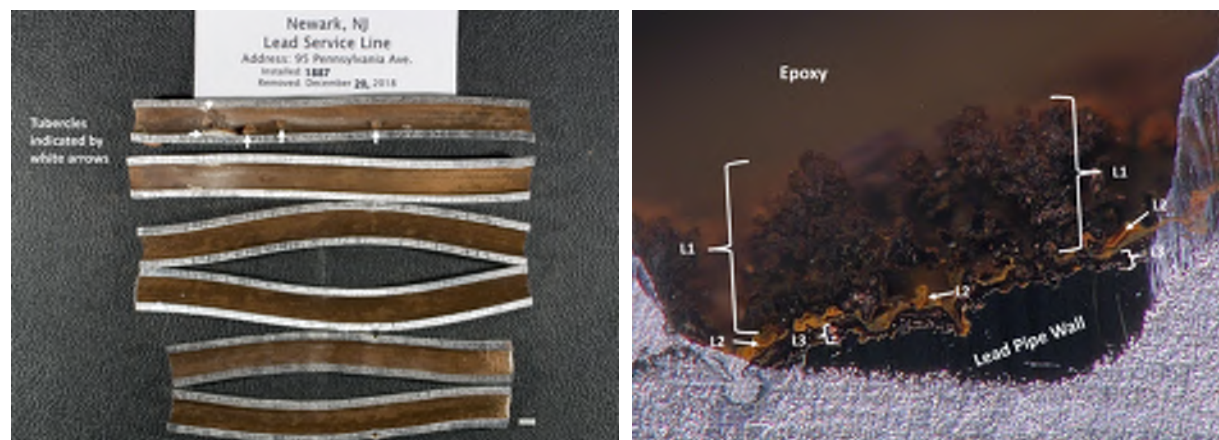


Figure 5-1 – Lead Scale Images for Pipe Extracted from 95 Pennsylvania Avenue

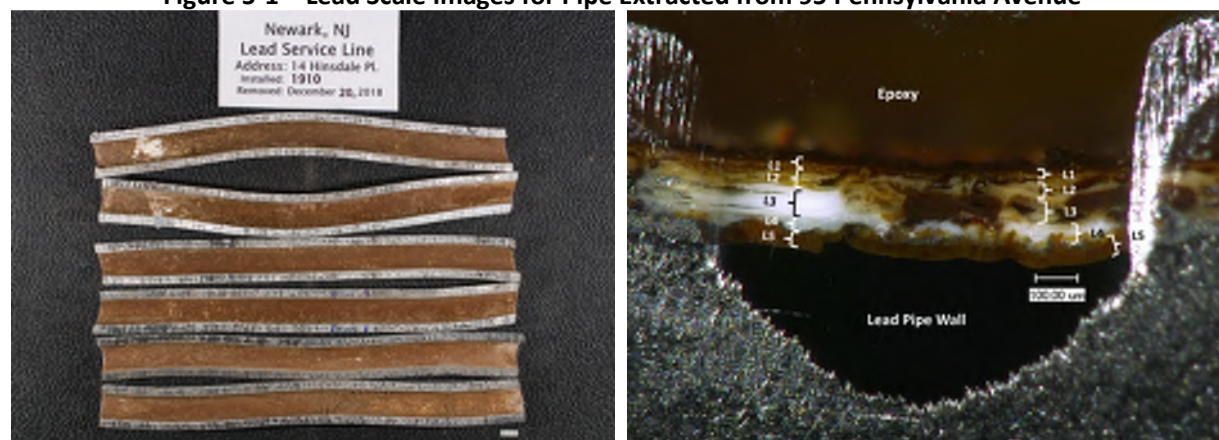


Figure 5-2 – Lead Scale Images for Pipe Extracted from 14 Hinsdale Place

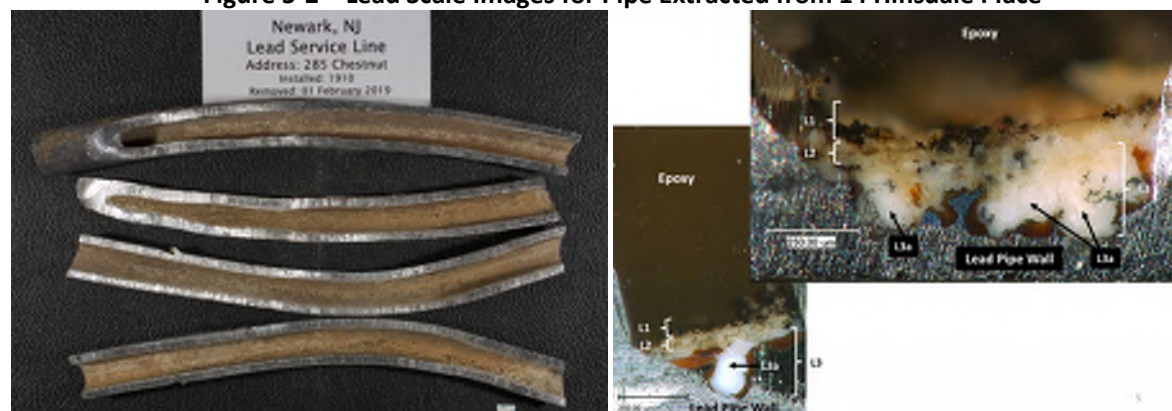


Figure 5-3 – Lead Scale Images for Pipe Extracted from 285 Chestnut Street

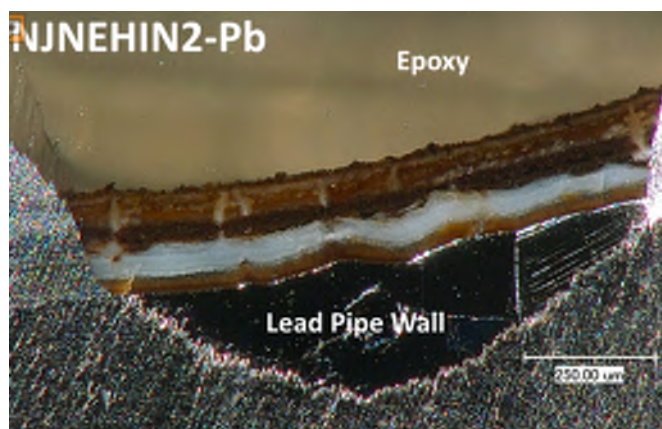


Figure 5-4 – Lead Scale Images for Pipe Extracted from 16 Hinsdale Place

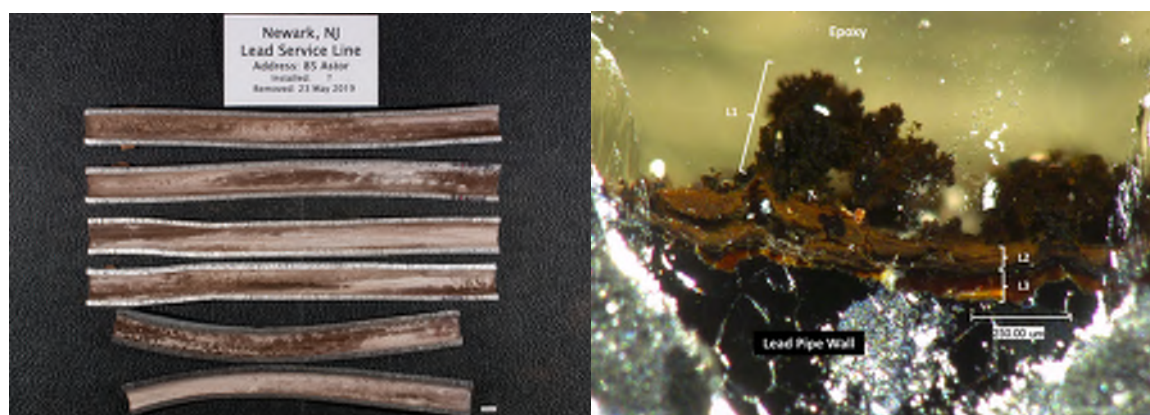


Figure 5-5 – Lead Scale Images for Pipe Extracted from 85 Astor Street

The scales found on the outermost layers were primarily plattnerite for 95 Pennsylvania Avenue and 85 Astor Street and calcium-hydroxypyromorphite with cerussite for 14 Hinsdale Place and 285 Chestnut Street. Per the cross section analysis, 16 Hinsdale Place did not seem to exhibit a plattnerite texture. The middle portion of the scale seemed to be characterized by the presence of phosphorous.

Plattnerite (PbO_2) is a tetravalent lead (Pb(IV)) compound that is formed over time in waters with high redox potential (ORP). It is reported in the literature that a high ORP can be achieved with free chlorine at levels typically over 1.5 mg/L, and that the rate of formation of PbO_2 appears to increase with increasing pH (Boyd, et al., 2008). Pb(IV) has been observed in systems with free chlorine residuals less than 1.5 mg/L, including Newark. ORP data is not available from within the Newark distribution system so correlations with chlorine residual are not possible. Under these conditions, PbO_2 typically dominates or coexists with Pb(II) mineral forms including hydrocerussite and cerussite. Plattnerite is less soluble than hydrocerussite and cerussite, making plattnerite more effective at achieving low lead levels when the proper (high ORP) water chemistry is maintained.

The pipe scales contain crystalline calcium-hydroxypyromorphite compounds, indicating that the phosphate complexation with lead is currently taking place to control soluble lead levels, as shown in the lead results discussed in Section 4.

Table 5-1 General Characterization of Solid Phases in Pipe Deposits

Location	Layer	Hydrocerussite Pb3(CO3)2(OH2)	Cerrusite Pb(CO3)	Plattnerite PbO2	Ca-hydroxypyromorphite Ca0.805Pb4.195(PO4)3(OH)	Litharge PbO	Laurionite Pb(OH)Cl	Plumbonacrite Pb5O(OH)2(CO3)3	Scrutinyite PbO2
95 Pennsylvania Avenue (East Ward)	L1		+	+++					+
	L2		+	+++					+
	L3		++	+++		++			+
14 Hinsdale Place (North Ward)	L1	+		+	+++				
	L2	+	+	+	+++				
	L3/L4		+++	+++	+++				
	L4	++	+++	+	+	+			
	L5	++	+++		+	+++			
285 Chestnut Street (East Ward)	L1	+	+	+	+++	+			
	L2	+	+	+	+++				
	L3a	++	+++		++	+			
	L3	+	+++		+	+++			
16 Hinsdae Place (North Ward)					No Data				
85 Astor Street (East Ward)	L1	+		+++	+				+
	L2	+		+++		+		+	+
	L3	+	++	++	+	+++			

Note: +++ = predominant, ++ = moderate, and + = trace/minor

5.2 EPA Elemental Analysis Testing and Results

An elemental analysis was also performed via X-ray diffraction (XRD) on the lead services lines discussed in **Section 5.1**. The XRD technology is able to assess the inorganic elemental composition of solid layers on the lead service lines through the solids extraction process. The EPA XRD results (**Appendix A**), provide the concentration of inorganic elements, expressed as micrograms per gram of solid (parts per million) or weight percent (AWWA, 2017).

To put the results below into context, the percentage (by weight) of lead (Pb) in the predominant scale complexes found on the pipes is 77.5% Pb in cerussite ($\text{Pb}(\text{CO}_3)$), 80.1% Pb in hydrocerussite ($\text{Pb}_3(\text{CO}_3)_2(\text{OH}_2)$), 86.6% Pb in Plattnerite (PbO_2), and 92.8% Pb in Litharge (PbO).

Table 5-2 provides a summary of the elemental data for the most common components found in each layer for the three locations. The sites are discussed individually below. The terminology “inner” refers to the scale layer directly against the lead pipe wall whereas “outer” refers to the scale layer in direct contact with the flowing water. The outermost layer is labeled as L1 and increases numerically, until reaching the innermost layer.

XRD analyses were able to be performed on undisturbed scales, which included only three of the lead pipes: 95 Pennsylvania Avenue, 14 Hinsdale Place and 285 Chestnut Street. The lead pipe from 85 Astor Street was also disturbed, but a small patch of what was believed to be relatively undisturbed scale was analyzed; however, it cannot be confirmed that the scale was undisturbed. Both 14 Hinsdale Place and 85 Astor Street lead pipes were disturbed from excavation. Cross-sectional images were taken to compare these scales to that from 16 Hinsdale Place and 95 Pennsylvania Avenue, respectively, based on proximity within the distribution system.

The lead scale composition of 14 Hinsdale Place was found to be similar to both 16 Hinsdale Place and 285 Chestnut Street. The scale composition for 85 Astor Street contained minor amounts of calcium-hydroxypyromorphite, which was not found in 95 Pennsylvania Avenue and rather in the scales of 14 Hinsdale Place and 16 Hinsdale Place.

5.2.1 95 Pennsylvania Avenue

The outermost layer had the greatest amount of silica (Si), iron (Fe), aluminum (Al), manganese (Mn), oxygen (O), phosphorous (P), calcium (Ca) which decreased in the subsequent layers. The outermost layer had the lowest amount of lead, which increased significantly toward the innermost layer. The general trend of increasing Pb from the outer to inner layers corresponds to the scale composition consisting of predominantly increasing amounts of PbO_2 to then consisting increasing amounts of PbO and $\text{Pb}(\text{CO}_3)$ in L3, as presented in **Table 5-1**. The increase in Pb in the layers moving from outer to inner is expected, as the inner layers are closer to the source of lead (the pipe). It should be noted that trench sediment was observed on the scale surface.

On the innermost layer, pockets were found across the length of the pipe and appear to indicate the beginning stages of tubercles observed in the pipe segment. The tubercles were located beneath a layer of plattnerite. The upper and lower layer of the tubercle test results are located in Appendix A. It should also be noted that tin found in the sample may have been from the analysis procedure. The surface texture of layer L3 was rippled and not all of layer L2 could be removed from the surface of layer L3.

Table 5-2 Summary of Scale Composition Elemental Analysis Results

Location	Layer	Elemental* % by Weight										
		Pb	Si	Fe	Al	Mn	O	P	Ca	C ^[1]	Cl	Sn
95 Pennsylvania Avenue (South Ward)	L1	58.6	1	2.3	1.4	7.4	23.6	1.1	1.2	< 0.5	No data	2.8
	L2	71.3	0.7	1.1	0.8	2.7	18.3	0.7	0.6	< 0.5	No data	3.1
	L3	83.6	No data	< 0.5	< 0.5	0.2	13.7	No data	No data	< 0.5	No data	1.4
14 Hinsdale Place (North Ward)	L1	40.8	8.8	7.5	2.6	1.2	32.1	3.1	1.5	1.01	No data	No data
	L2	62.5	2	3.1	0.9	< 0.5	22.5	4.8	2.5	1.28		
	L3/L4	75.9	No data	< 0.5	< 0.5	< 0.5	16.4	3.2	1.7	1.93		
	L4	80.1		< 0.5	< 0.5	No data	15.4	0.7	< 0.5	2.98		
	L5	85.0		< 0.5	< 0.5		12.9	< 0.5	< 0.5	1.37		
285 Chestnut Street (East Ward)	L1	78.0	1	2.6	0.77	2.6	No data	4.9	3	1.21	1.3	0.5
	L2	82.0	< 0.5	< 0.5	< 0.5	0.54		7.4	4	1.29	2.1	< 0.5
	L3a	88.0	< 0.5	< 0.5	0.61	< 0.5		2.4	1.3	2.39	0.81	No data
	L3	98.0	< 0.5	< 0.5	< 0.5	< 0.5		1.3	0.7	1.18	0.68	< 0.5
16 Hinsdale Place (North Ward)	No Data											
85 Astor Street (South Ward)	No Data											

*Pb = lead; Si = silica; Fe = iron; Al = aluminum; Mn = manganese; Na = sodium; [O= oxygen](#); [Mg=mangnesium](#); [P=phosphorous](#); [Ca= calcium](#)

[\[1\] By combustion](#)

Note: No data infers the mineral phase was either not present or below the detection limit

5.2.2 14 Hinsdale Place

The outermost layer had the greatest amount of silica (Si), iron (Fe), aluminum (Al), manganese (Mn), and oxygen (O) which substantially decreased in the subsequent layers. The high level of silica (Si) in the outermost layer is likely due to the quartz grains in the trench sediments that were scattered over the scale surface. The elements that were greater in the outermost three layers and then substantially decreased in the innermost layer, were phosphorous (P), calcium (Ca) and carbon (C). Both the phosphorous (P) and calcium (Ca) concentrations correspond with the scale composition consisting of predominantly a calcium-hydroxypyromorphite mineral phase in the outermost three layers, which forms in the presence of phosphate. Other elements were traced in the lead layers, but were less than 0.5% by weight, such as magnesium (Mg), sodium (Na), sulfur (S), titanium (Ti), and potassium (K). It should be noted that trench sediment was observed on the scale surface and contained visible mica and small rock fragments.

The outermost layer had the lowest amount of lead (Pb), which significantly increased in the innermost layers. The general trend of increasing Pb from the outer to inner layers corresponds to the scale composition consisting of calcium lead phosphate hydroxide (calcium-hydroxypyromorphite) to a mix of lead carbonate and PbO in L5. The increase in Pb in the layers moving from outer to inner is expected, as the inner layers are closer to the source of lead (the pipe).

5.2.3 285 Chestnut Street

The outermost layer had the greatest amount of carbon (C), aluminum (Al), silica (Si), phosphorous (P), chloride (Cl), tin (Sn), manganese (Mn), and iron (Fe), which substantially decreased in the subsequent layers. Calcium (Ca) was also higher in the outermost layer, increased in the second layer and decreased substantially in the subsequent layers. Other elements were traced in the lead layers, but were less than 0.5% by weight, such as sulfur (S), chromium (Cr), copper (Cu), zinc (Zn), and nickel (Ni).

The outermost layer had the lowest amount of lead (Pb), which significantly increased in the innermost layers. The general trend of increasing Pb from the outer to inner layers corresponds to the scale composition consisting of predominantly a calcium-hydroxypyromorphite mineral phase in the outermost two layers. The increase in Pb in the layers moving from outer to inner is expected, as the inner layers are closer to the source of lead (the pipe). The calcium-hydroxypyromorphite mineral phase was also predominant in the 14 Hinsdale Place lead pipe.

5.2.4 16 Hinsdale Place

Due to disturbance of the lead pipe scale during excavation, it was not possible to complete the elemental analysis and XRD analysis for this scale. However, a cross sectional analysis was performed via SED/EMS mapping and indicates the scale appears to be consistent with what was found in 14 Hinsdale Place (i.e., predominantly calcium-hydroxypyromorphite, which forms in the presence of phosphate).

5.2.5 85 Astor Street

Also due to disturbance of the scales, it was not possible to complete the elemental analysis. However, a small patch of what was believed to be relatively undisturbed scale was able to be analyzed to identify the crystalline mineral compounds. It should be noted that it cannot be

certain that the scale was undisturbed. Based on the data available, the lead scale consisted predominantly of plattnerite and had trace amounts of calcium-hydroxypyromorphite, whereas calcium-hydroxypyromorphite was predominant in the 14 Hinsdale Place and 285 Chestnut Street lead pipe scales and plattnerite was predominant in the 95 Pennsylvania Avenue lead pipe scale.

5.3 Analysis of Results

5.3.1 Comparison of Sequential Sampling Results and Scale Analysis

More dominant plattnerite scales were found on the pipes harvested in 95 Pennsylvania Avenue and 85 Astor Street, but there was also plattnerite found in the scale for 14 Hinsdale. Plattnerite is a tetravalent lead scale and is similar to what was found on the scales in the Pequannock Gradient. However, unlike Pequannock, the plattnerite scales in the Wanaque Gradient appear to be stable and effectively controlling lead release. Calcium-hydroxypyromorphite, which are stable crystalline compounds formed in the presence of phosphate presumably from the orthophosphate addition, were found as the dominant scales at 14 Hinsdale Place, 16 Hinsdale Place and 285 Chestnut Avenue. A summary of the dominant scales and related water quality data are provided in **Table 5-3**.

In December 2018 and January 2019, Newark closed the partially open division gate valves that caused Pequannock water to flow into the Wanaque Gradient. The flushed water samples during the sequential sampling showed higher levels of orthophosphate in the samples that were taken after the division gates were closed compared with the samples taken prior to the division gates being closed. However, the orthophosphate levels did not always align with a dominant calcium-hydroxypyromorphite crystalline scale in the samples tested. For example, low concentrations of orthophosphate were found at 14 Hinsdale Place, however a calcium-hydroxypyromorphite scale was observed. Conversely, orthophosphate was present in the water at 95 Pennsylvania Avenue and 85 Astor Street, yet a calcium-hydroxypyromorphite crystalline scale was not the dominant scale in these locations.

The scale analyses conducted on LSLs in the Wanaque Gradient is an example that, even with orthophosphate addition, a phosphate-based crystalline scale is not necessarily the solubility-controlling phase. For this specific system, while the scale morphology varies throughout the system, the scales appear to be functioning to control lead solubility. This is evidenced by the majority of low lead levels at the tap in the LCR compliance sampling and the low lead levels found in the sequential sampling performed for this study.

Table 5-3 – Comparison of Water Quality Data and EPA Scale Analysis Results

Address	Chlorine Residual (mg/L)		pH		Orthophosphate (mg/L PO ₄)		Date Sampled ^[1]	Date Excavated	Most Prominent Scale Compound Found
	1 st /2 nd Liter	Flushed Sample	1 st /2 nd Liter	Flushed Sample	1 st /2 nd Liter	Flushed Sample			
95 Pennsylvania Avenue (South Ward)	N/A	N/A	N/A	N/A	1.19	1.64	12/14/18	12/21/18	Plattnerite > cerrusite > litharge
85 Astor Street (South Ward)	0.93	0.89	7.8	7.78	1.56	1.56	4/16/19	5/23/19	Plattnerite > litharge > cerrusite > calcium-hydroxypyromorphite
14 Hinsdale Place (North Ward)	N/A	N/A	N/A	N/A	<0.3	<0.3	12/14/18	12/21/18	Calcium-hydroxypyromorphite > cerrusite > plattnerite
16 Hinsdale Place (North Ward)	0.19	0.67	6.6	6.63	<0.3	2.30	1/21/19	3/12/19	Calcium-hydroxypyromorphite
285 Chestnut Street (East Ward)	0.03	0.36	6.25	6.36	1.99	2.10	1/11/19	2/2/19	Calcium-hydroxypyromorphite > cerrusite > litharge

[1] The water quality provided is from testing before the LSLR.

Section 6

Recommendations

Based on the information available and presented herein, CDM Smith does not recommend modifications to the corrosion control treatment for the Wanaque Gradient at this time. The Wanaque Gradient has not experienced concerning levels of soluble and particulate lead that are currently being experienced in the Pequannock Gradient.

Based on the scale analyses, the corrosion control mechanism in the Wanaque Gradient is currently a combination of phosphate crystalline scales (calcium-hydroxypyromorphite), plattnerite (tetravalent lead) scales and carbonate scales. The scales are providing protection against lead corrosion which is evident in the LCR compliance tap sampling and the sequential sampling that was performed for this study. Therefore, it is not recommended that treatment or corrosion control parameters be modified in the Wanaque Gradient for the purposes of further improving lead corrosion control.

Several factors may be contributing to the makeup and stability of the scales in the Wanaque Gradient including:

- An orthophosphate dose of 1.8 to 2.2 mg/L as PO₄ operating within an effective pH range
- Robust treatment at the NJDWSC plant, including clarification for organics removal
- Stable water quality making the system less vulnerable to seasonal changes

In addition to effective corrosion control treatment, there are measures the City can take to help further protect residents from lead in drinking water when there are lead-containing materials in their home plumbing:

- **Public Education** – It is recommended that the City continue with the public education campaign to encourage residents to understand the risks of lead in their drinking water when they have a lead service line or lead solder in copper plumbing.
- **Lead Service Line Replacement Program** – The City has embarked on a city-wide lead service line replacement program to replace the homeowner-owned lead service line with a copper line for \$1,000 to anyone within the City of Newark. The City should continue to encourage homeowners and landlords to sign up for this program.
- **Flushing in Wanaque** – Based on the results of the sequential sampling in Newark and in other cities and towns, even with corrosion control treatment, lead particles can migrate through a scale barrier into the drinking water. This particularly occurs after periods of low water usage, stagnation or anything that disturbs a lead service line or lead solder. It is recommended that residents understand the need to flush their lines after a stagnation period or after disturbance. In all 12 sequential sampling events performed within the

Wanaque Gradient, the flushed samples were typically below 2 ppb indicating that the scale is stable and that flushing is an effective means of reducing lead concentrations.

- **Lead Testing at the Tap** – Newark currently provides free lead testing to all residents in Newark. If a test result from a home located in the Wanaque Gradient is above 15 ppb, Newark provides a free filter to that resident.

It is recommended that the City continue to routinely monitor the results from ongoing water quality parameter and compliance sampling to identify and understand any changes that may take place. If **any** treatment modifications are proposed by NJDWSC or the City, the impact on the current corrosion control mechanisms would need to be further evaluated.

It is CDM Smith's opinion that optimal WQPs can be set for the Wanaque Gradient at this time to monitor and guide the consistency of the delivered water quality.

Appendix A

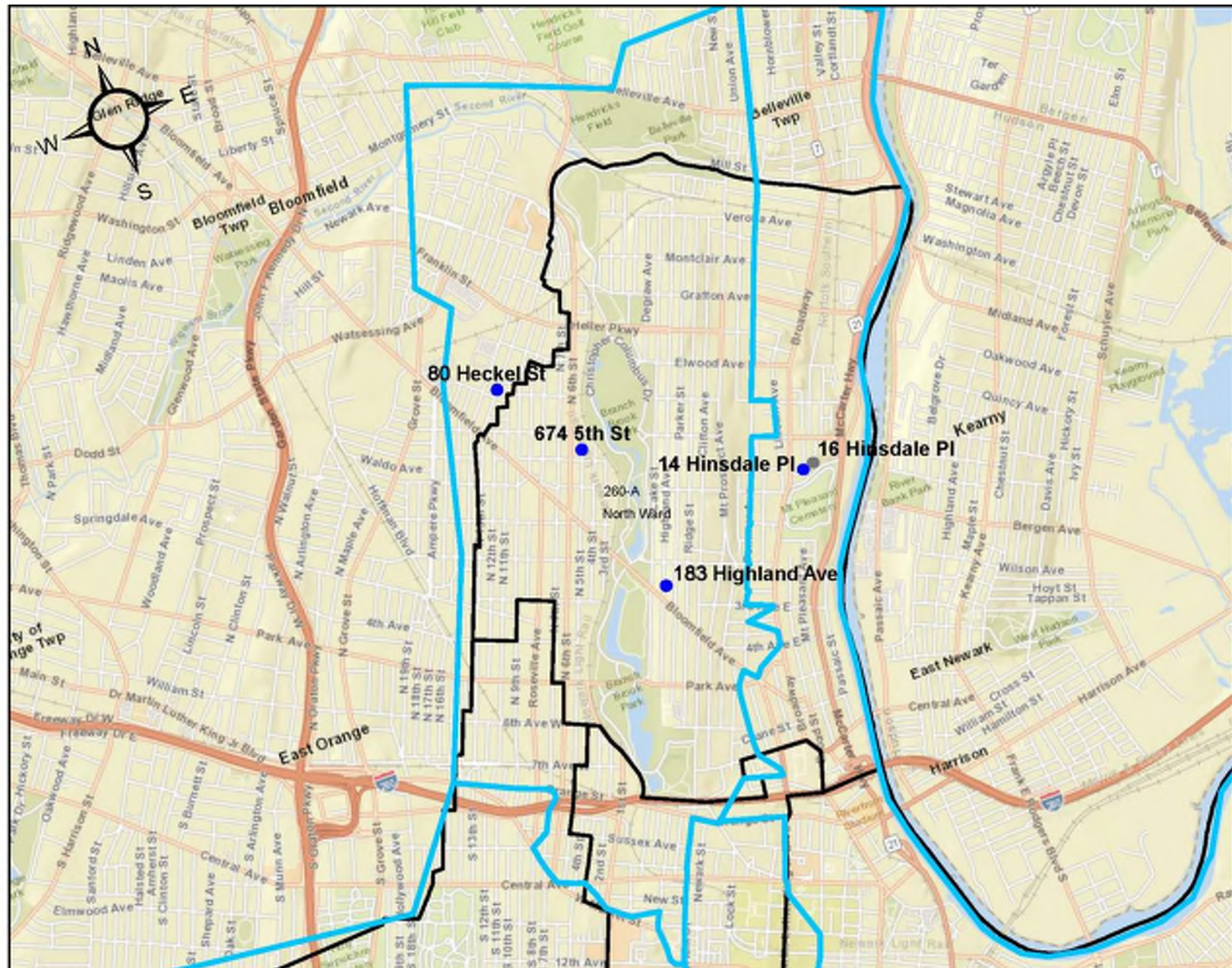
Wanaque Pipe Scale Analysis

Newark, NJ

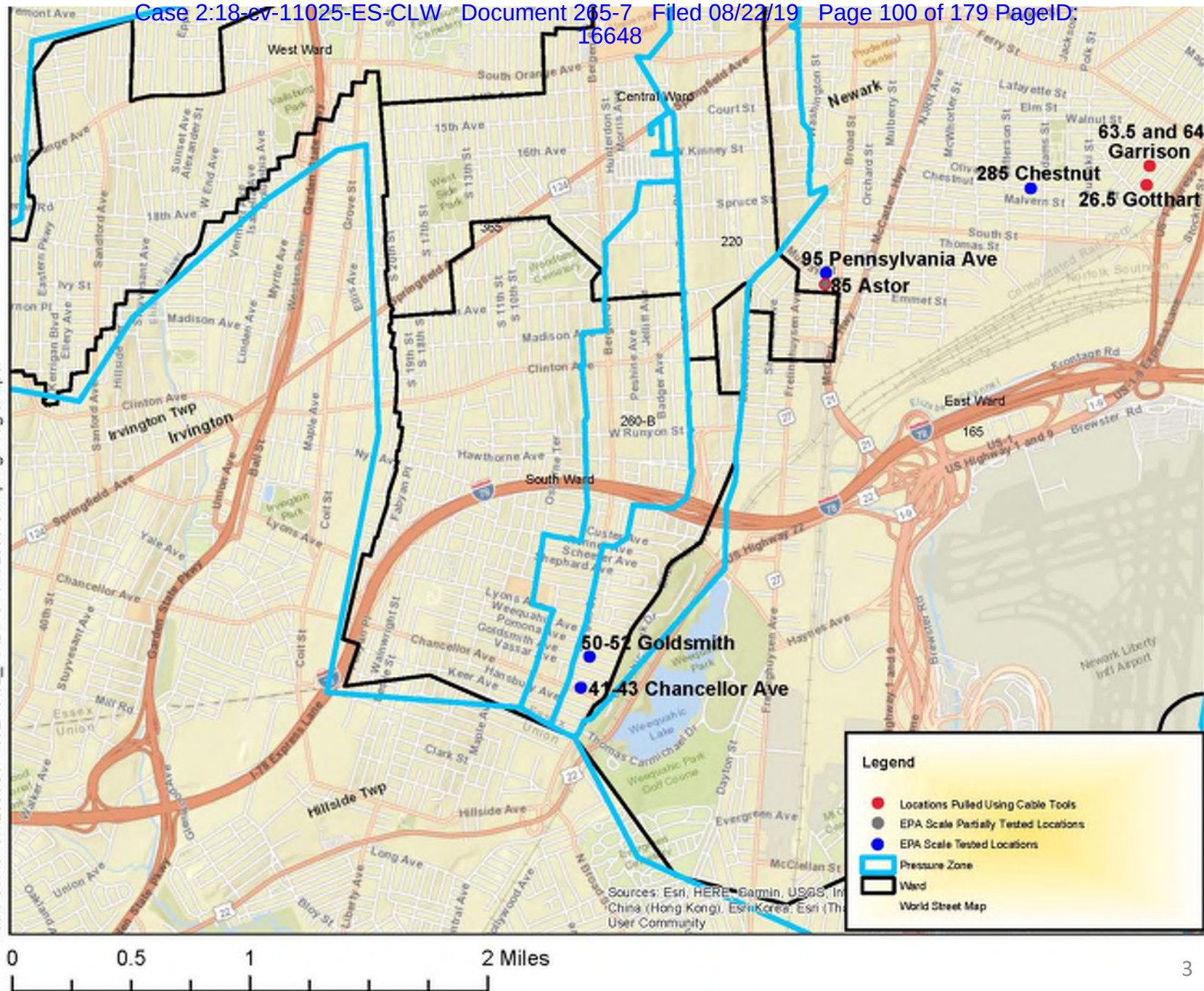
LSL samples extracted in December 2018, and February, March, May 2019

For more information, please contact:

Michael Schock, schock.michael@epa.gov, (513) 569-7412



Path: G:\NewarkLeadService\Line02_MXD\Newark Lead Sampling Program.pdf





Newark, NJ
Lead Service Line
Address: 285 Chestnut
Installed: 1910
Removed: 01 February 2019



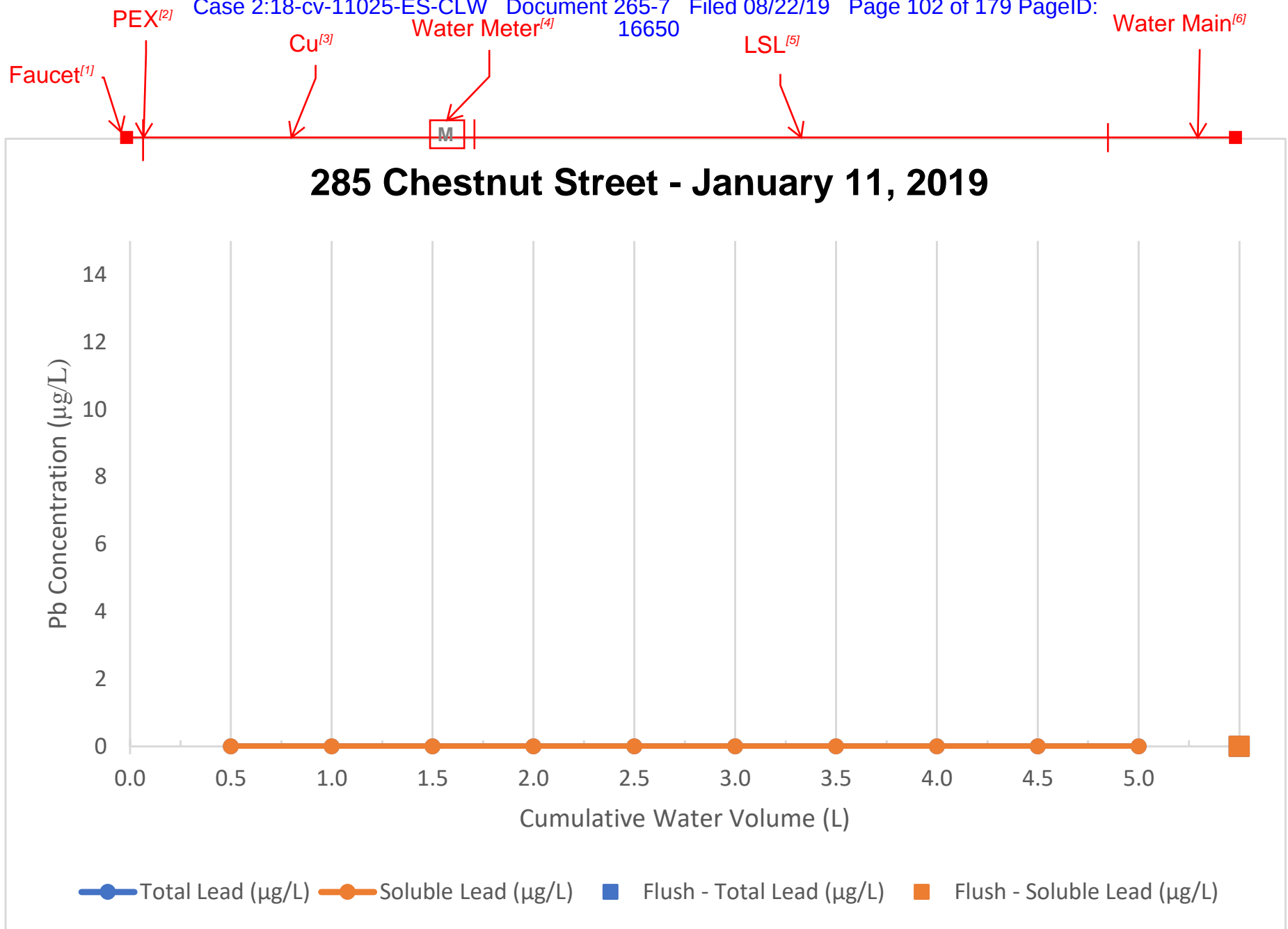
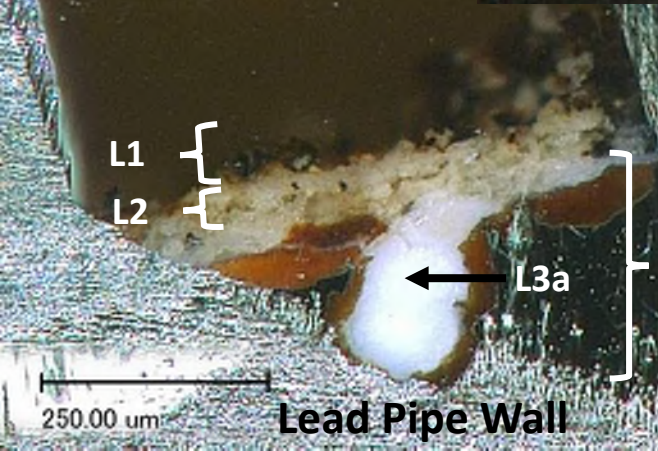
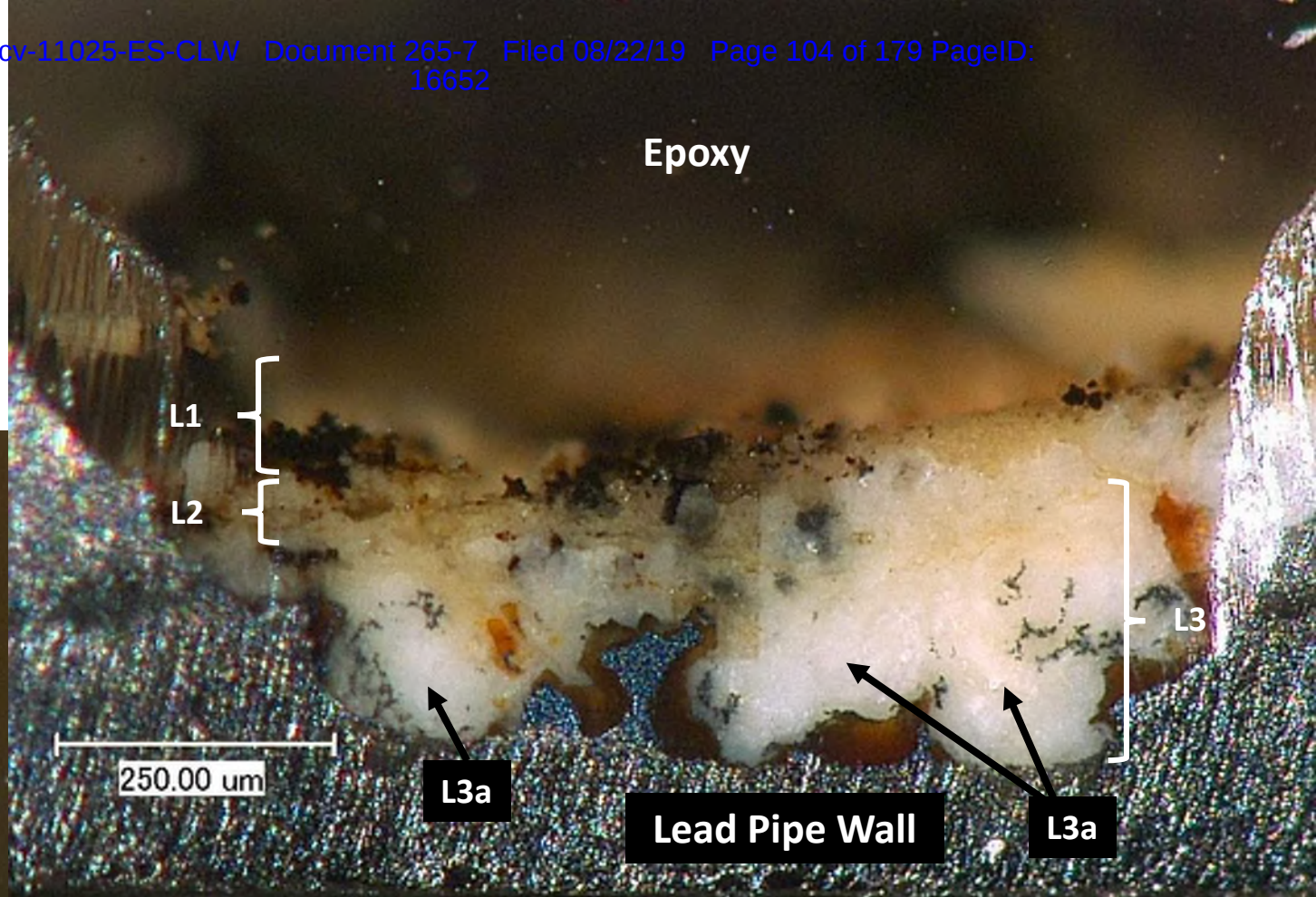


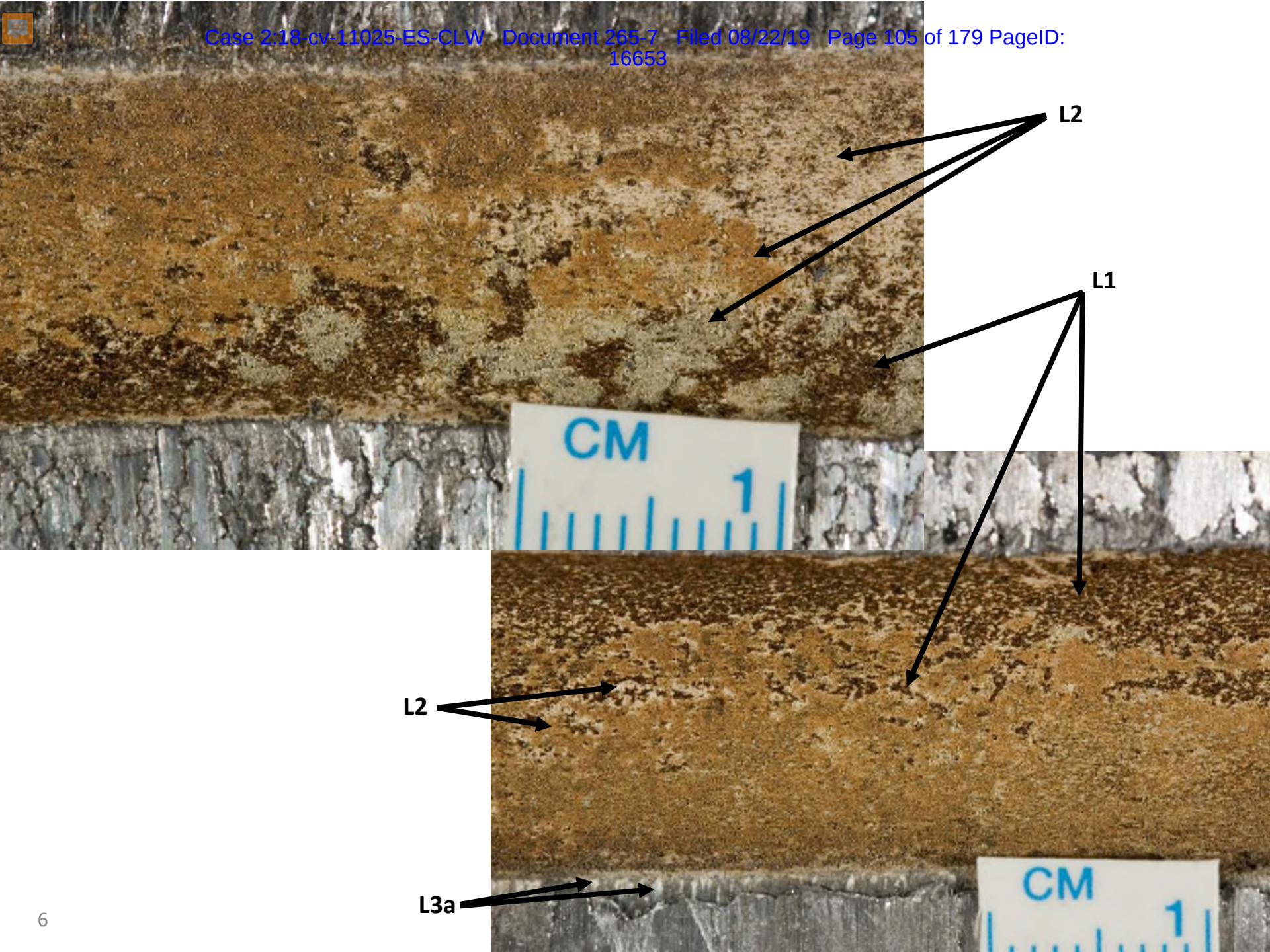
Table 1-1H
City of Newark Sequential Monitoring
Analytical Results
285 Chestnut St

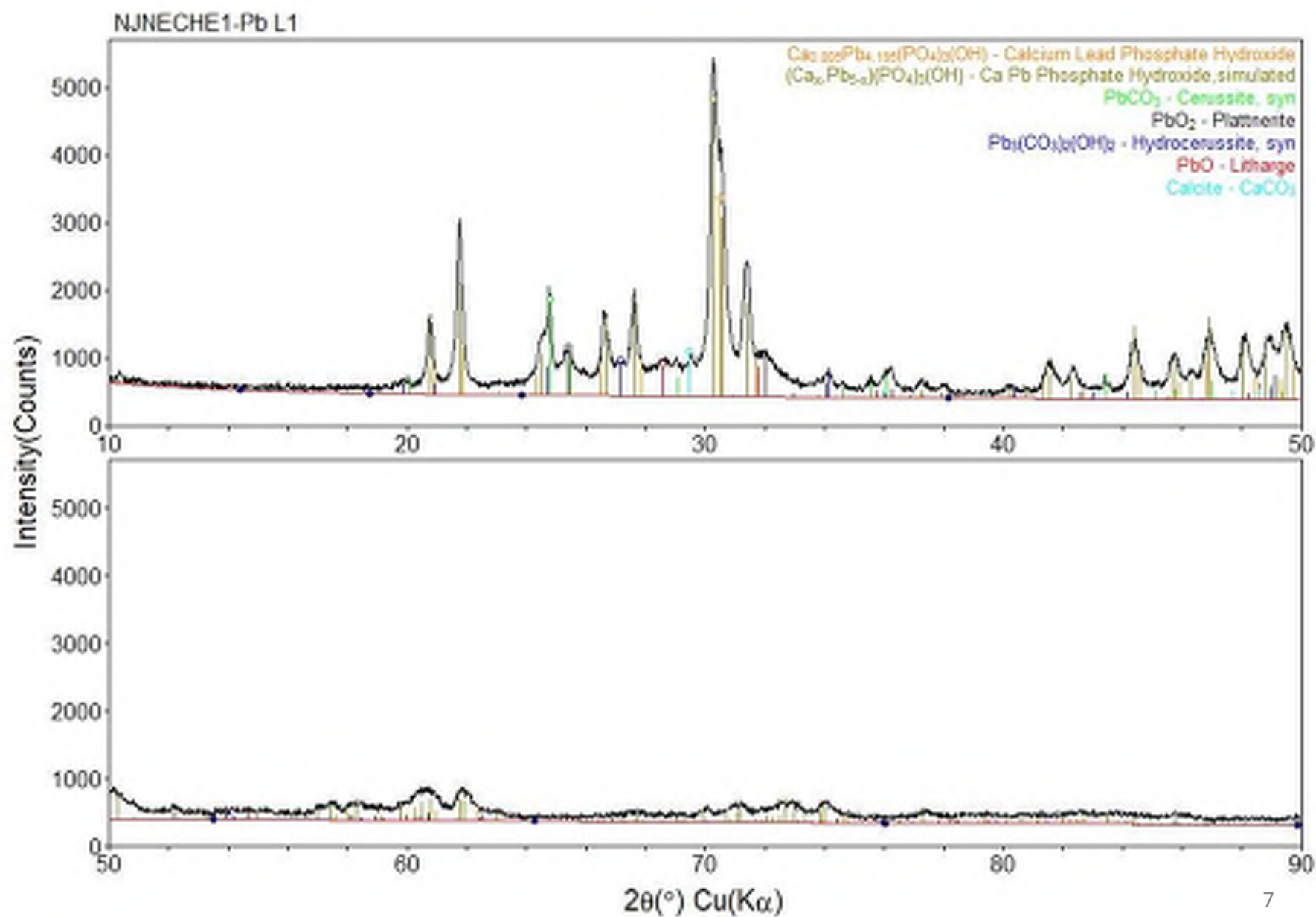
Site H - 1/11/19

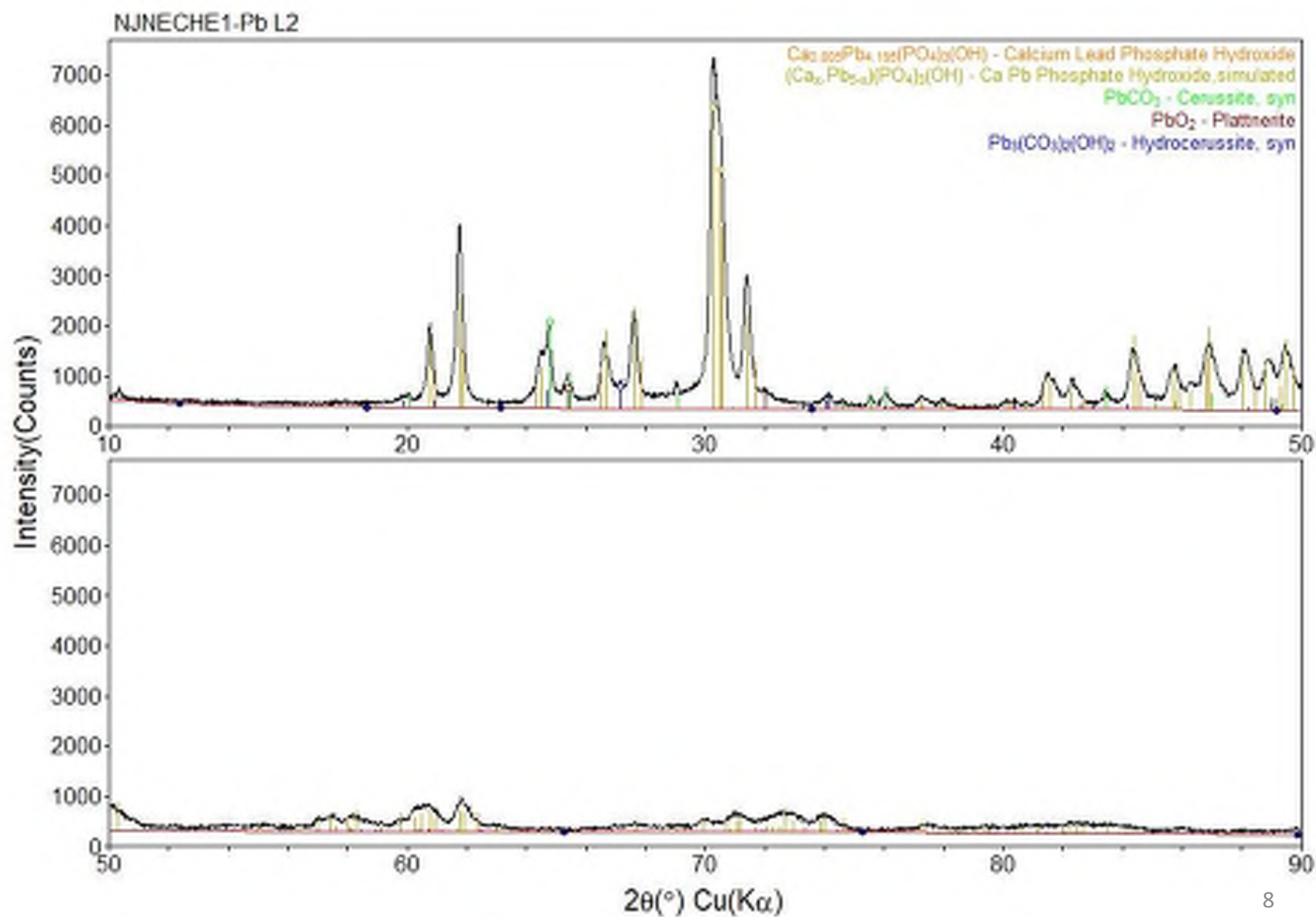
Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹ (degrees C)	Free Cl ₂ ¹ (mg/L)	Total Pb (µg/L)	Dissolved Pb (µg/L)	Total Cu (mg/L)	Alk. (mg/L as CaCO ₃)	Cond. umhos/cm	Orthophosphate (mg/L as P)	Silica (mg/L as SiO ₂)	
H1	500	500	After Stagnation	6.25	17.4	0.03	<2	<2	<.05	32.0	243			Faucet (6% Black PEX or Black SS Braided) and Copper Piping with No Lead Solder (97%)
H2	500	1000	After Stagnation				<2	<2	<.05			0.663	3.46	Copper Piping(100%)
H3	500	1500	After Stagnation				<2	<2	<.05					Lead Piping (100%)
H4	500	2000	After Stagnation				<2	<2	<.05					Lead Piping (100%)
H5	500	2500	After Stagnation				<2	<2	<.05					Lead Piping (100%)
H6	500	3000	After Stagnation	6.3	18	0.14	<2	<2	<.05	32	242		3.76	Lead Piping (100%)
H7	500	3500	After Stagnation				<2	<2	<.05			0.705		Lead Piping (100%)
H8	500	4000	After Stagnation				<2	<2	<.05					Lead Piping (100%)
H9	500	4500	After Stagnation				<2	<2	<.05					Lead Piping (100%)
H10	500	5000	After Stagnation				<2	<2	<.05					Lead Piping (50%); Water Main (50%)
H11 FLUSH	500	5500	Flushed after the sequential sampling	6.36	20	0.36	<2	<2	<.05	31.0	240	0.7	3.75	Water Main (100%)

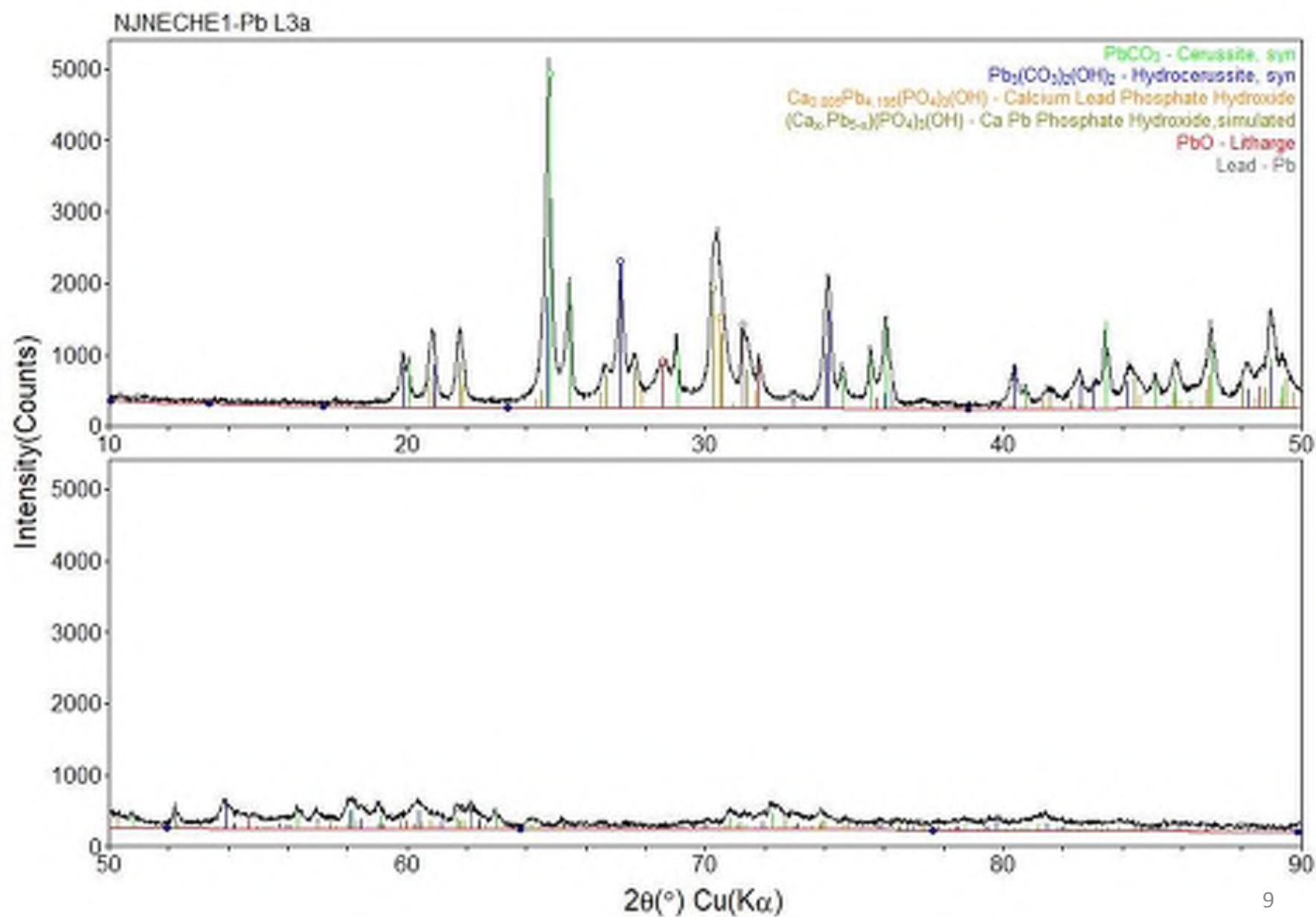
- NOTES
1. pH, temperature, and free and total chlorine will be field measured.
 2. **HOMEOWNER SHOULD FLUSH THE LINE FOR 10 MINUTES BEFORE BEGINNING STAGNATION PERIOD (i.e. night before sampling).**

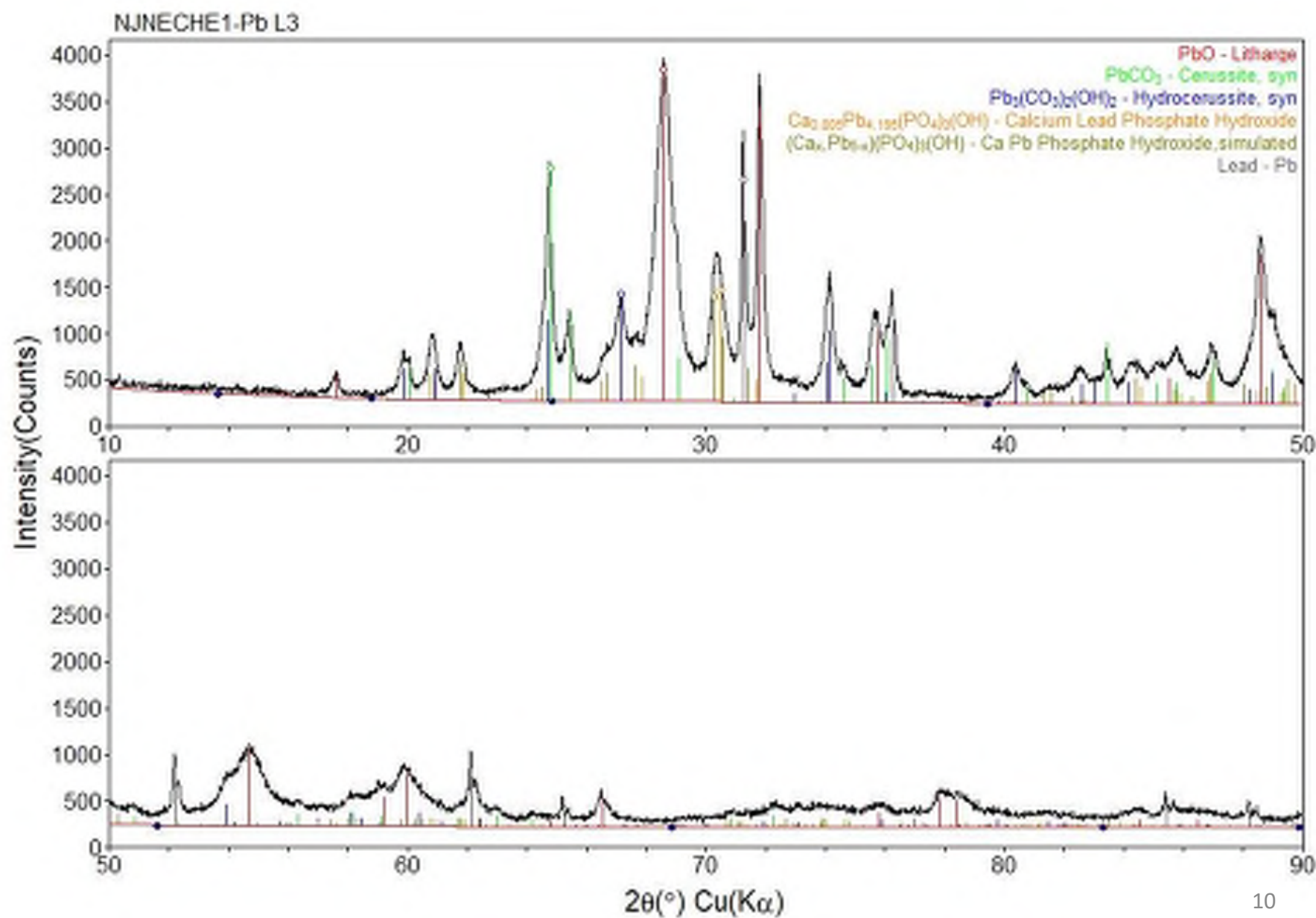


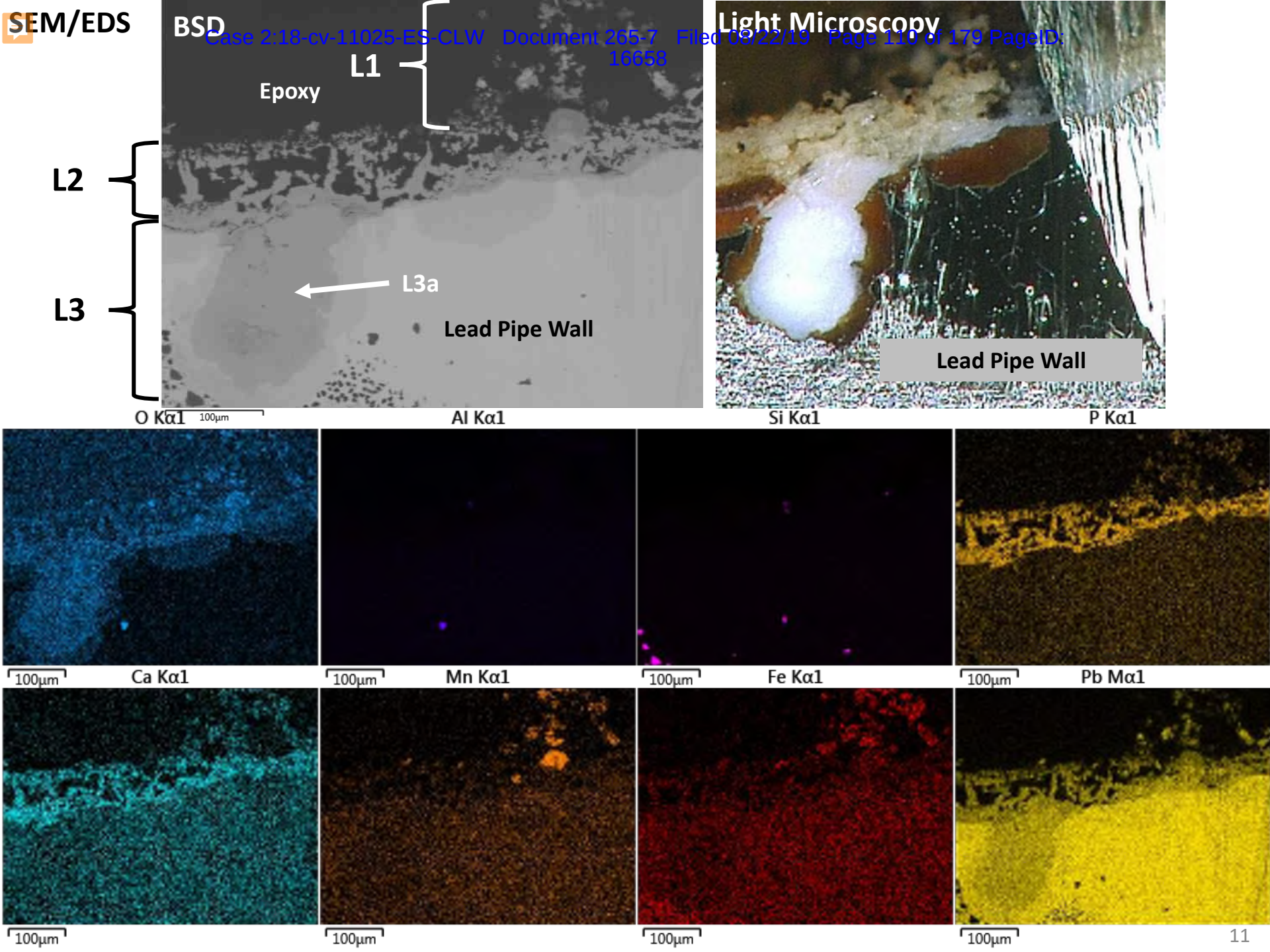


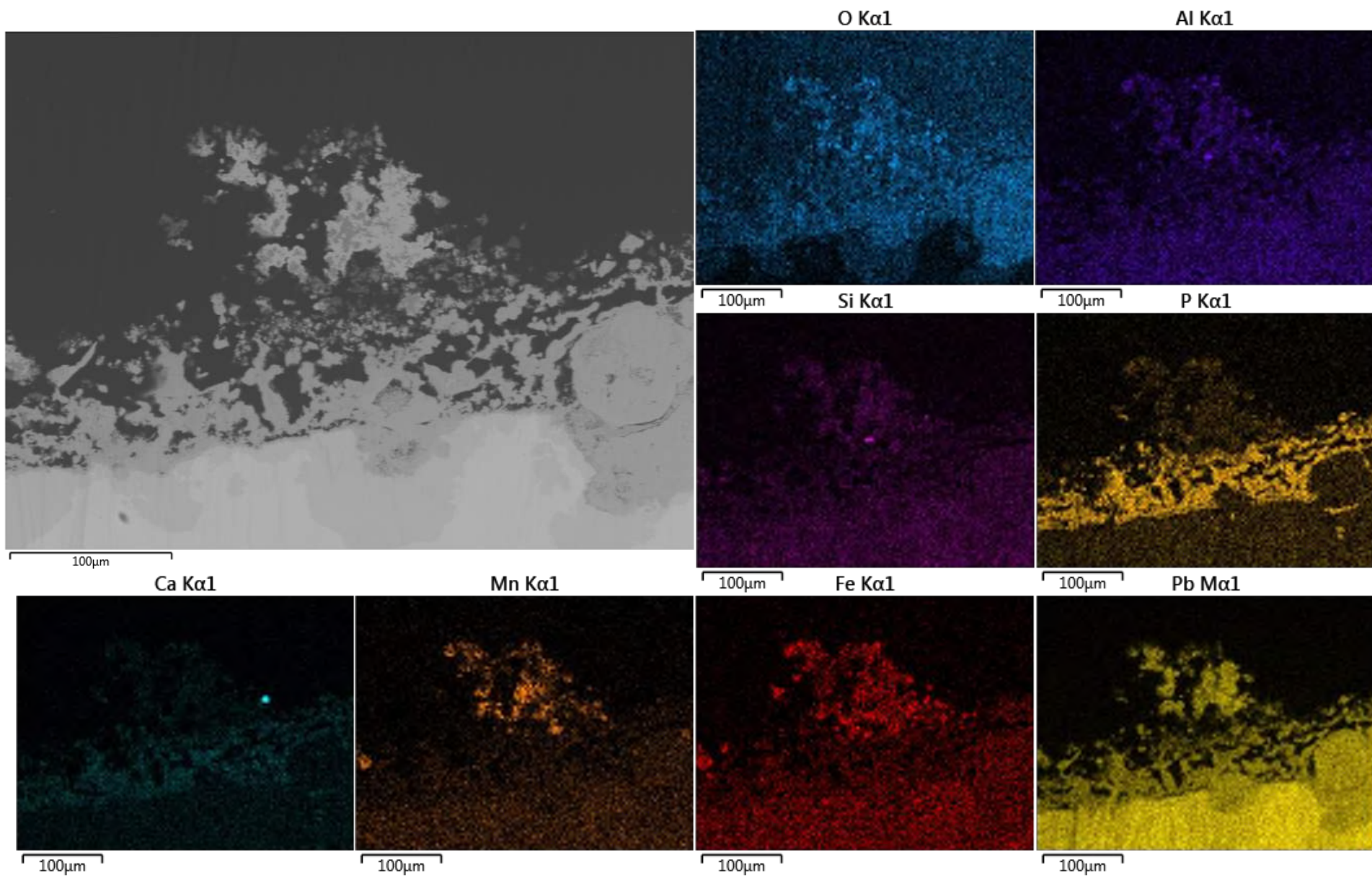


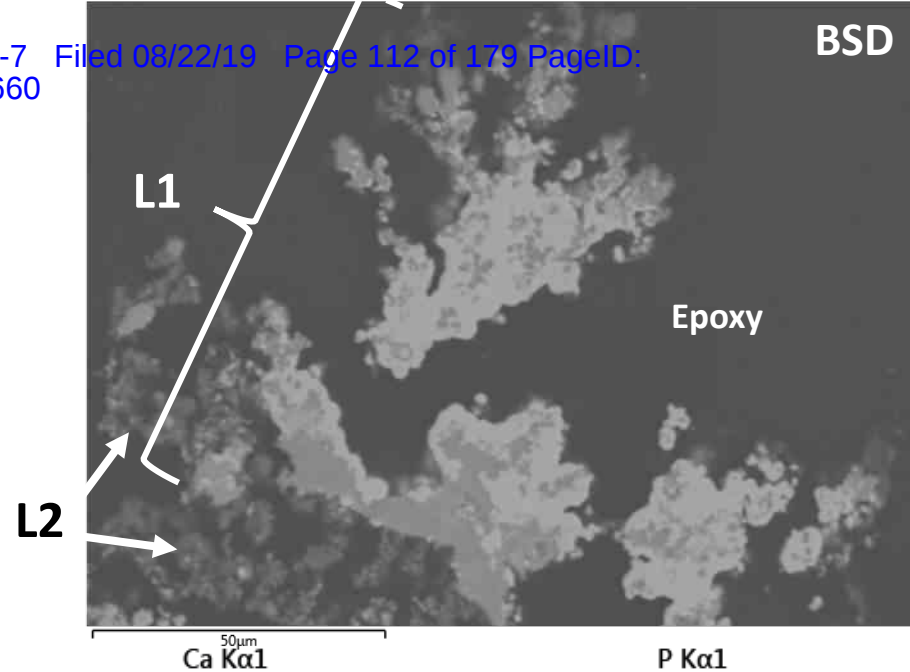
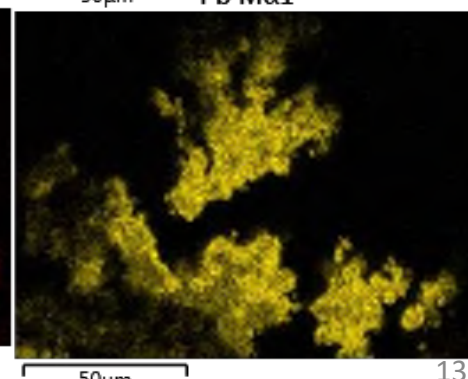
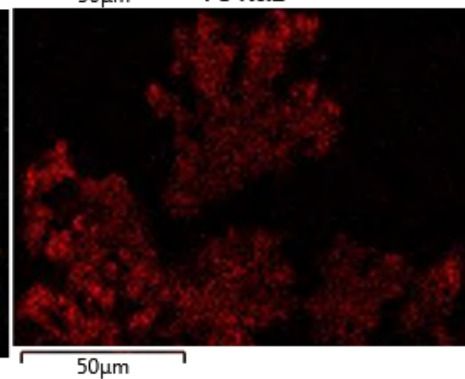
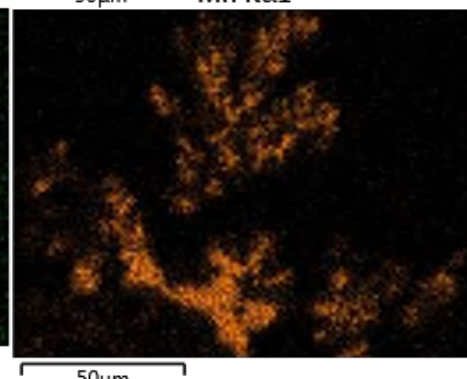
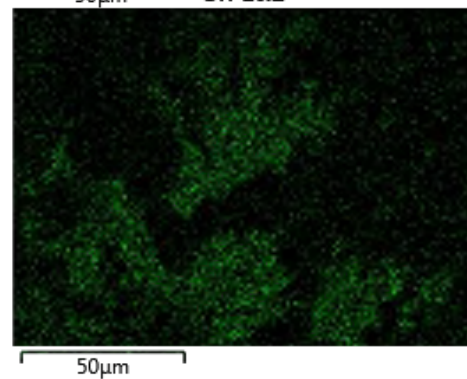
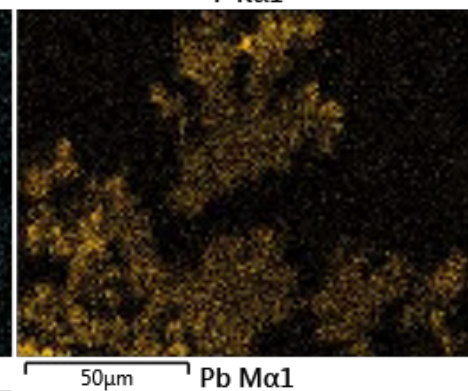
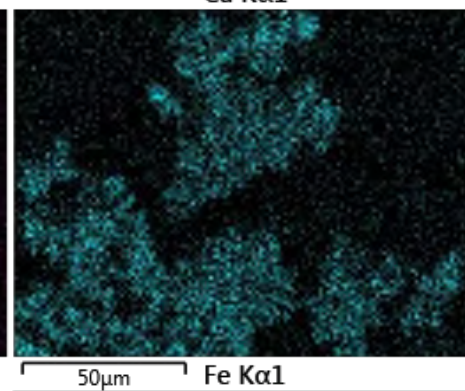
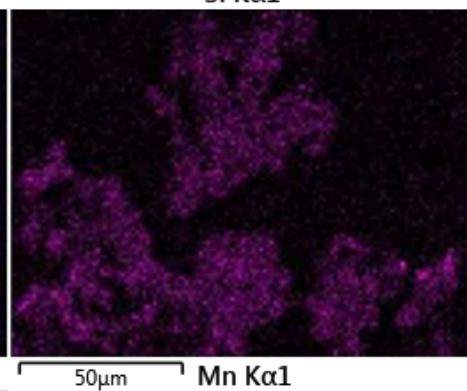
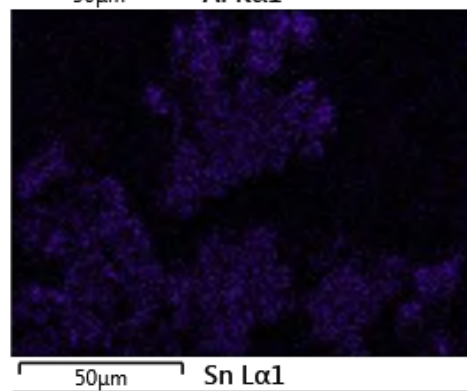
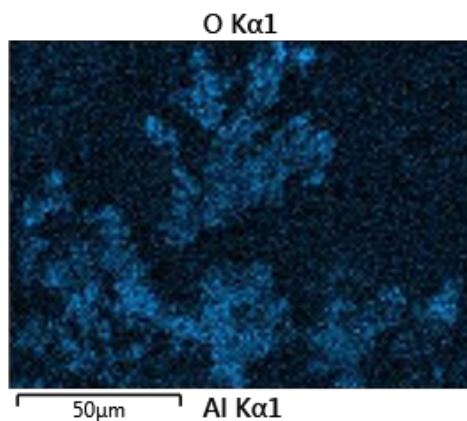


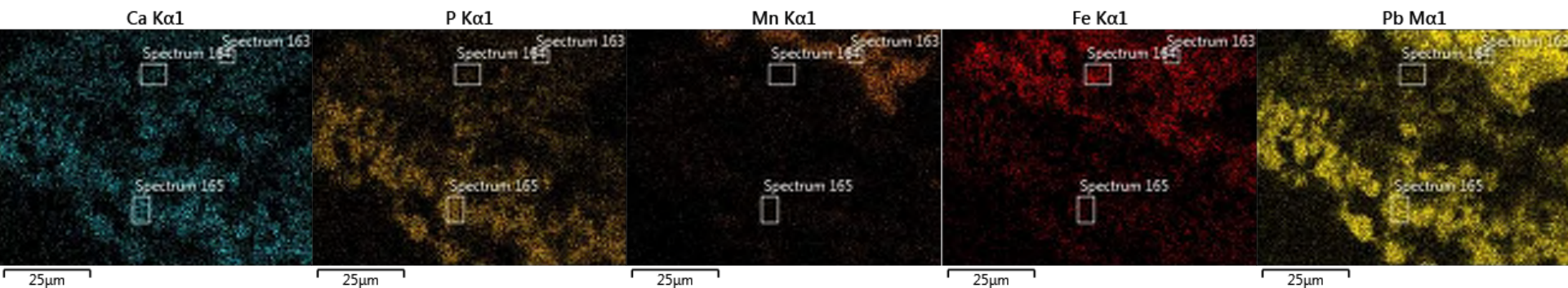
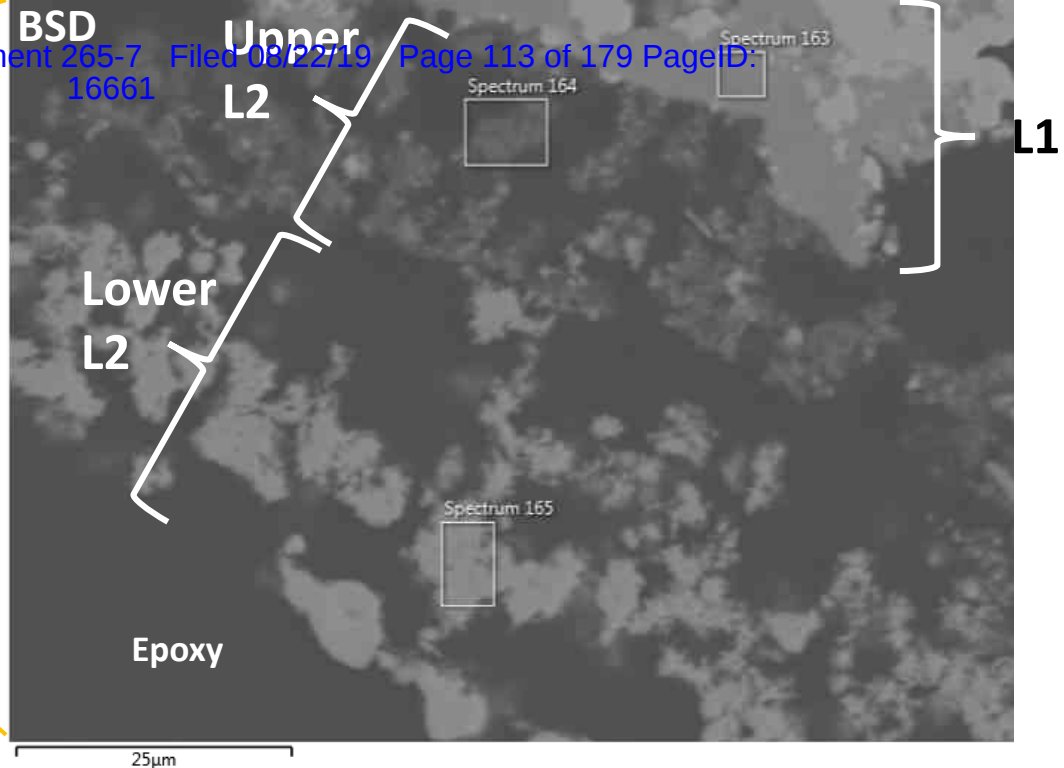
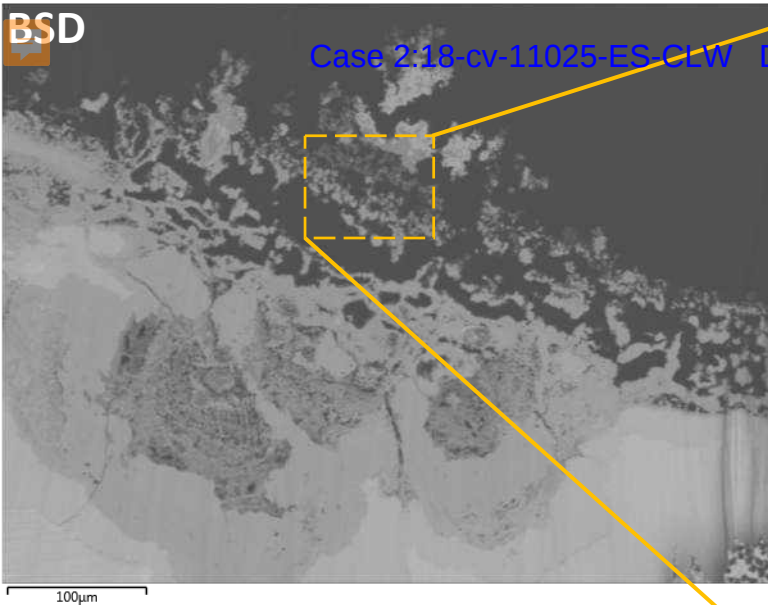












Spectrum #	Elements in Decreasing Abundance
163	Pb, Mn, Fe, P, Si, Ca, Al, V, Sn, Mg
164	Pb, Fe, P, Si, Ca, Mn, Al, Sn, Mg (* less Mn than 163)
165	Pb, P, Ca, Al, Mg

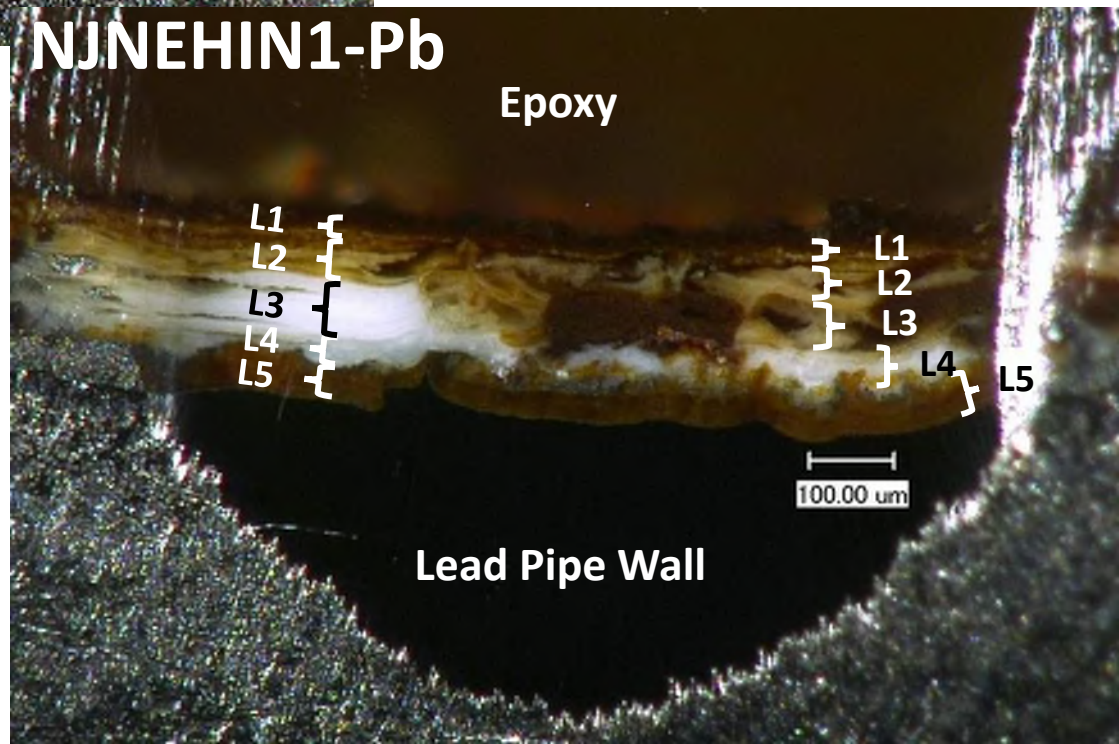
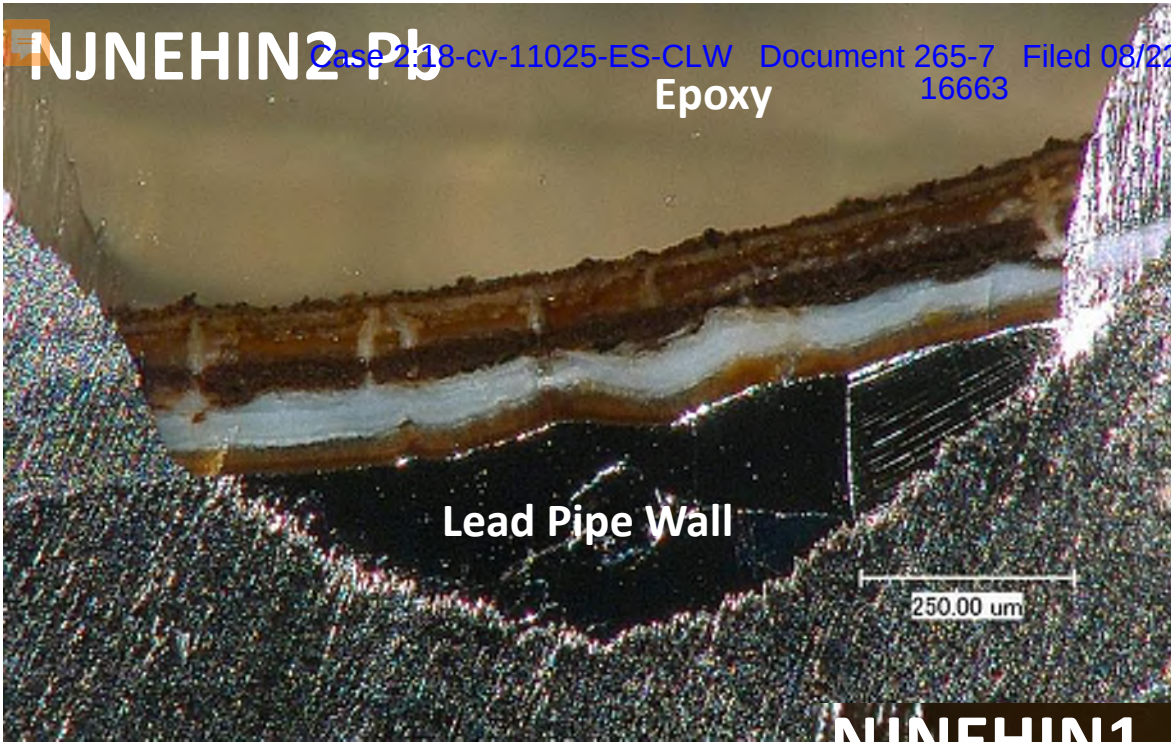


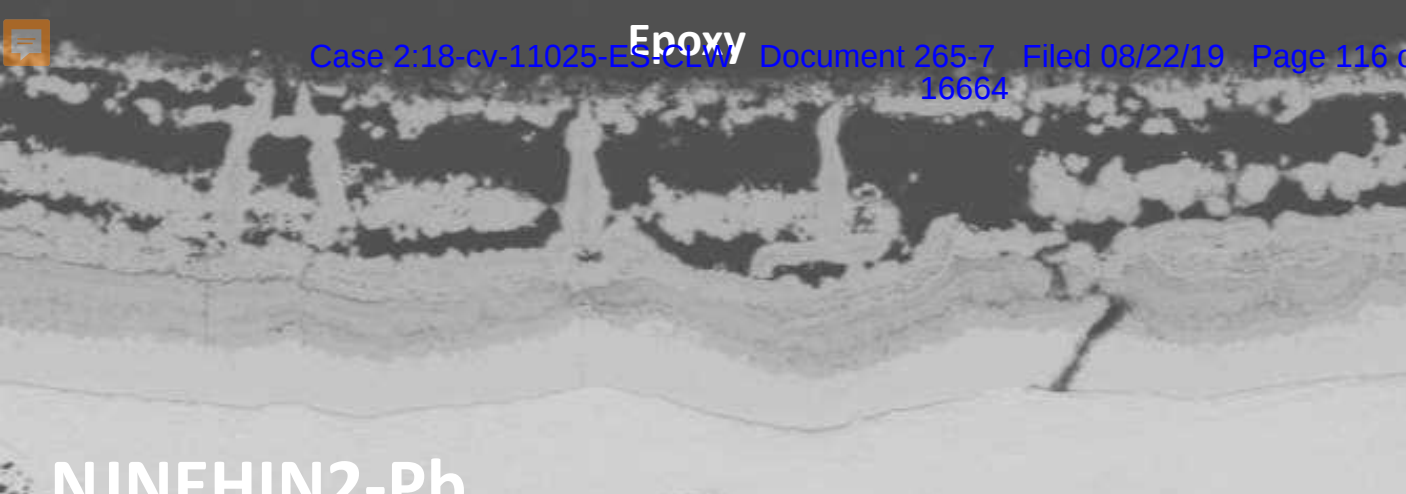
XRF Results

Elemental Concentrations as Average wt%

NJNECHE1-Pb				
Elements	L1	L2	L3a	L3
*C	1.21	1.29	2.39	1.18
Al	0.77	0.4	0.61	0.24
Si	1	0.18	0.29	0.073
P	4.9	7.4	2.4	1.3
*S	0.13	0.12	0.36	0.12
Ca	3	4	1.3	0.7
Cl	1.3	2.1	0.81	0.68
Cr	0.044	-	-	-
Cu	0.23	0.1	0.2	0.09
Sn	0.5	0.41	-	0.2
Zn	0.055	0.033	-	-
Mn	2.6	0.54	0.11	0.041
Fe	2.6	0.45	0.19	0.08
Ni	0.026	0.036	0.11	-
Pb	78	82	88	98

*C and S by combustion

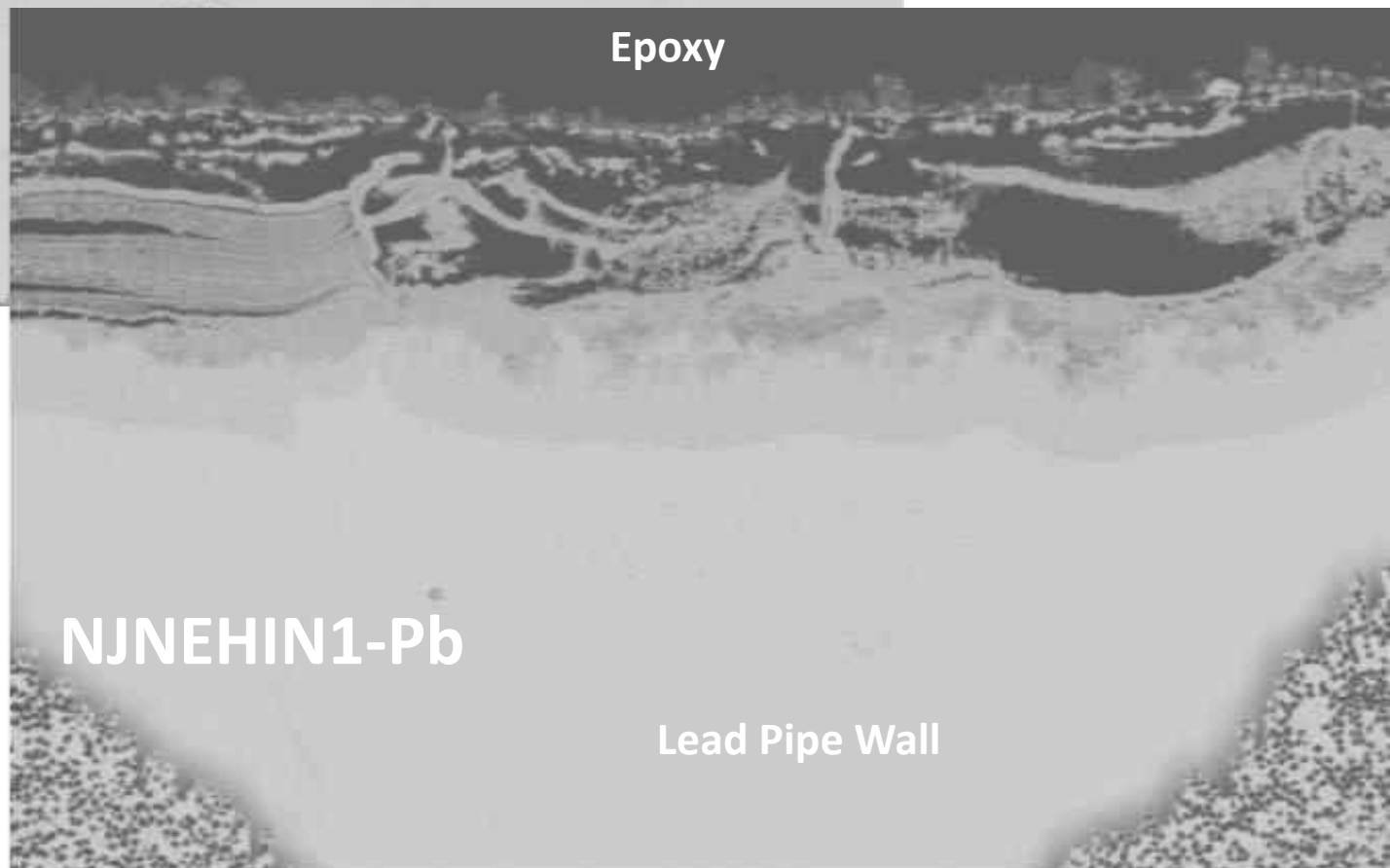




NJNEHIN2-Pb

Lead Pipe Wall

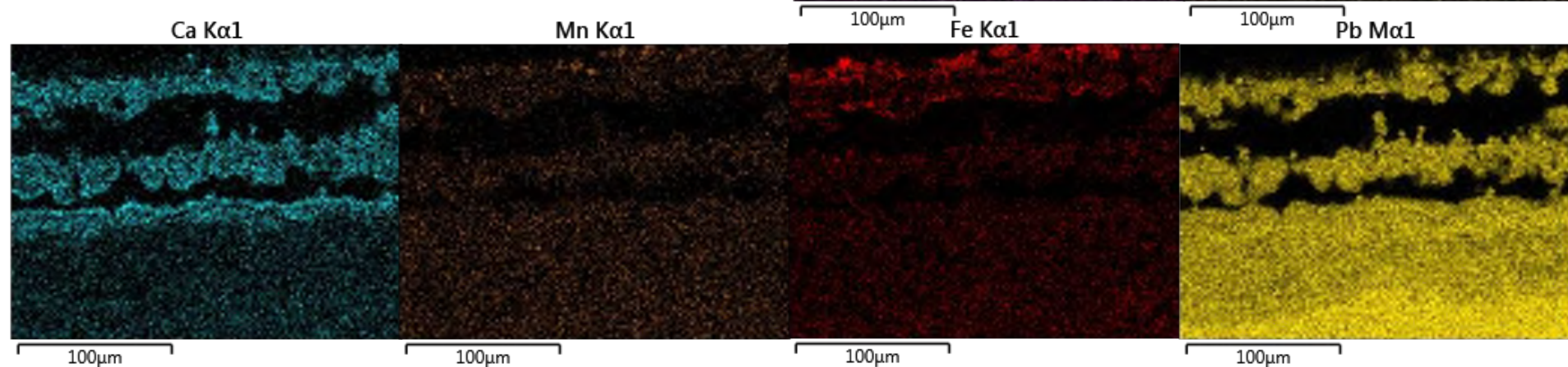
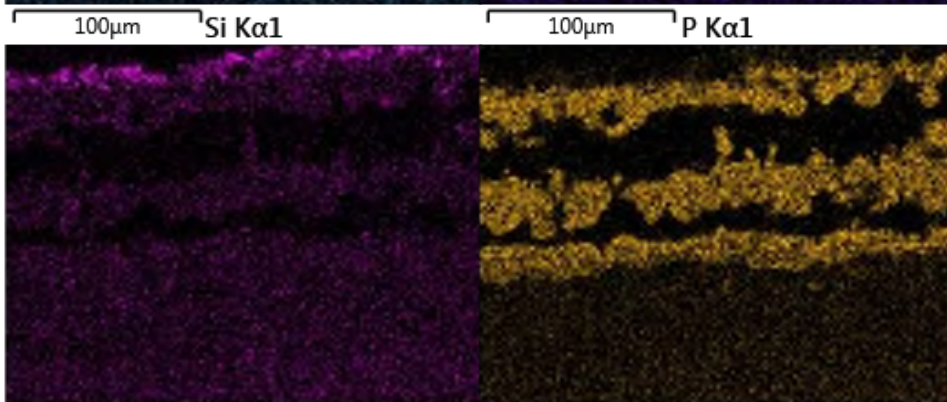
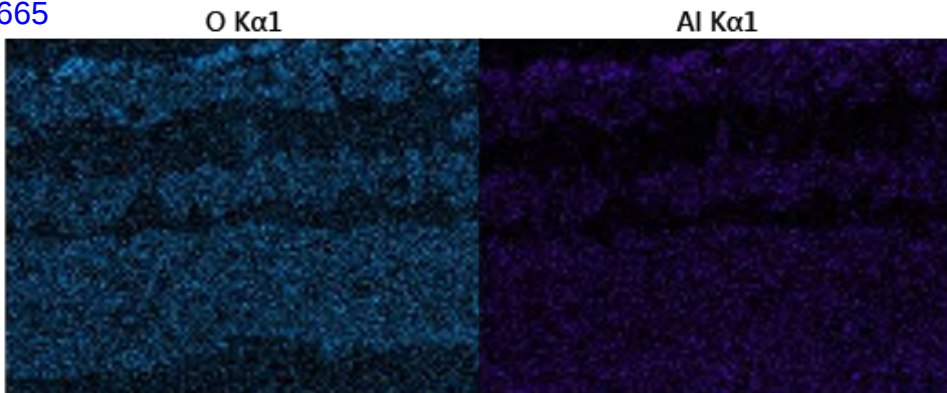
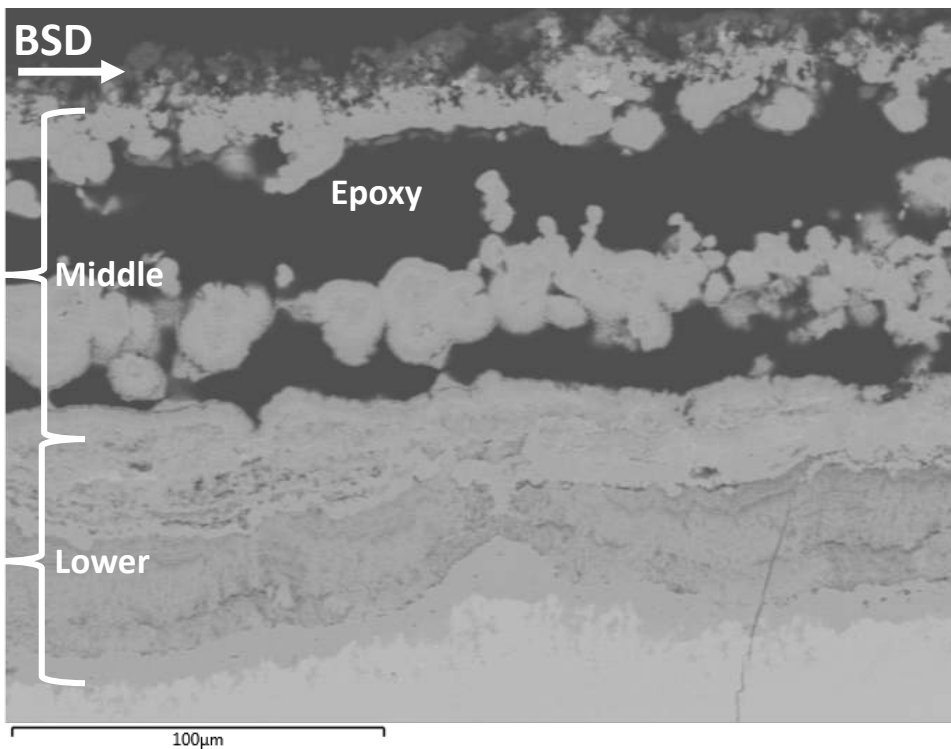
250μm

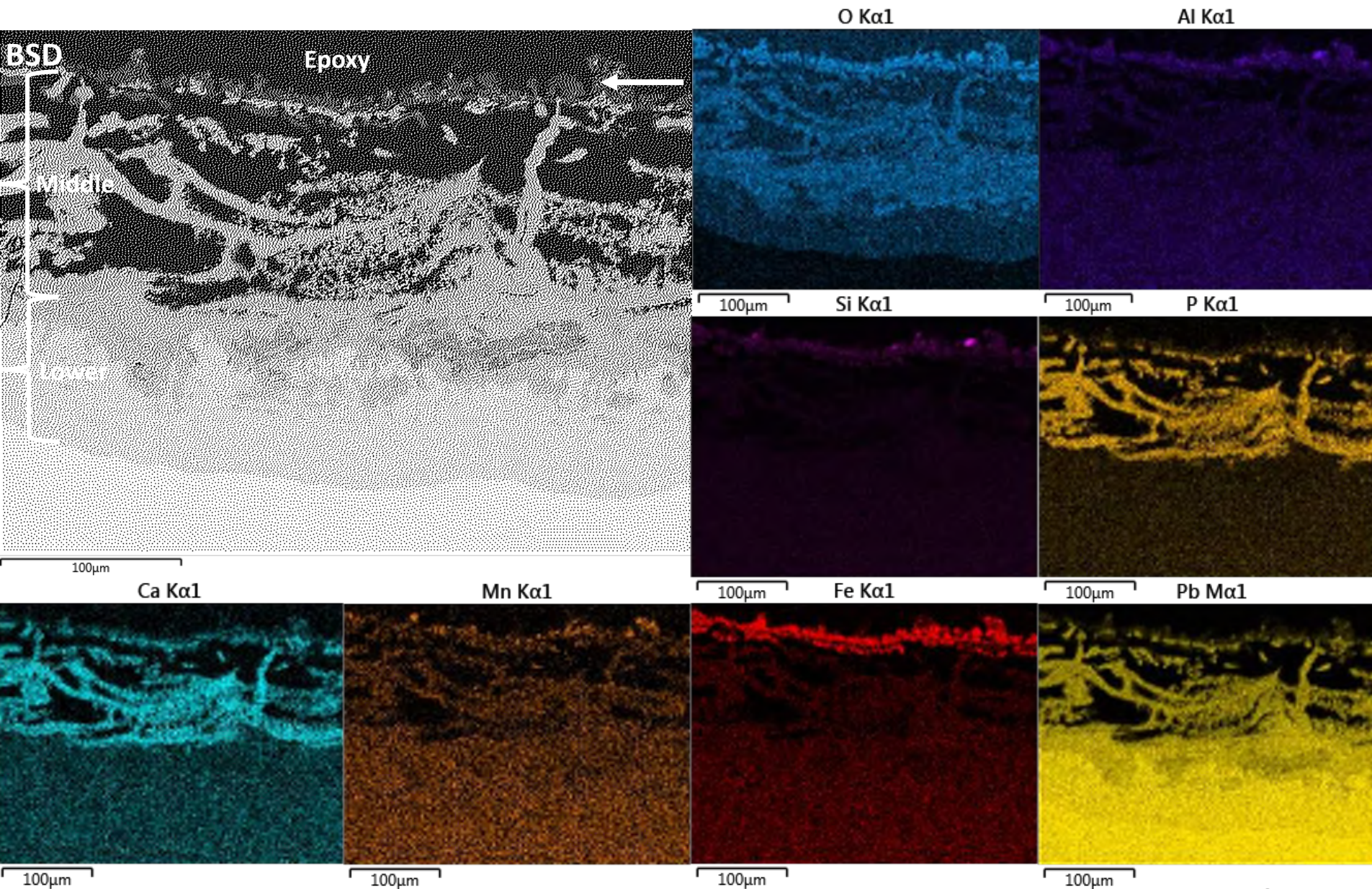


NJNEHIN1-Pb

Lead Pipe Wall

250μm







Newark, NJ
Lead Service Line
Address: 85 Astor
Installed: ?
Removed: 23 May 2019



Faucet^[1]

Cu^[2]

Water Meter^[3]

Galvanized Steel^[4]

LCV^[5]

Water Main^[6]

M

85 Astor Street - Lead Profiling - April 16, 2019

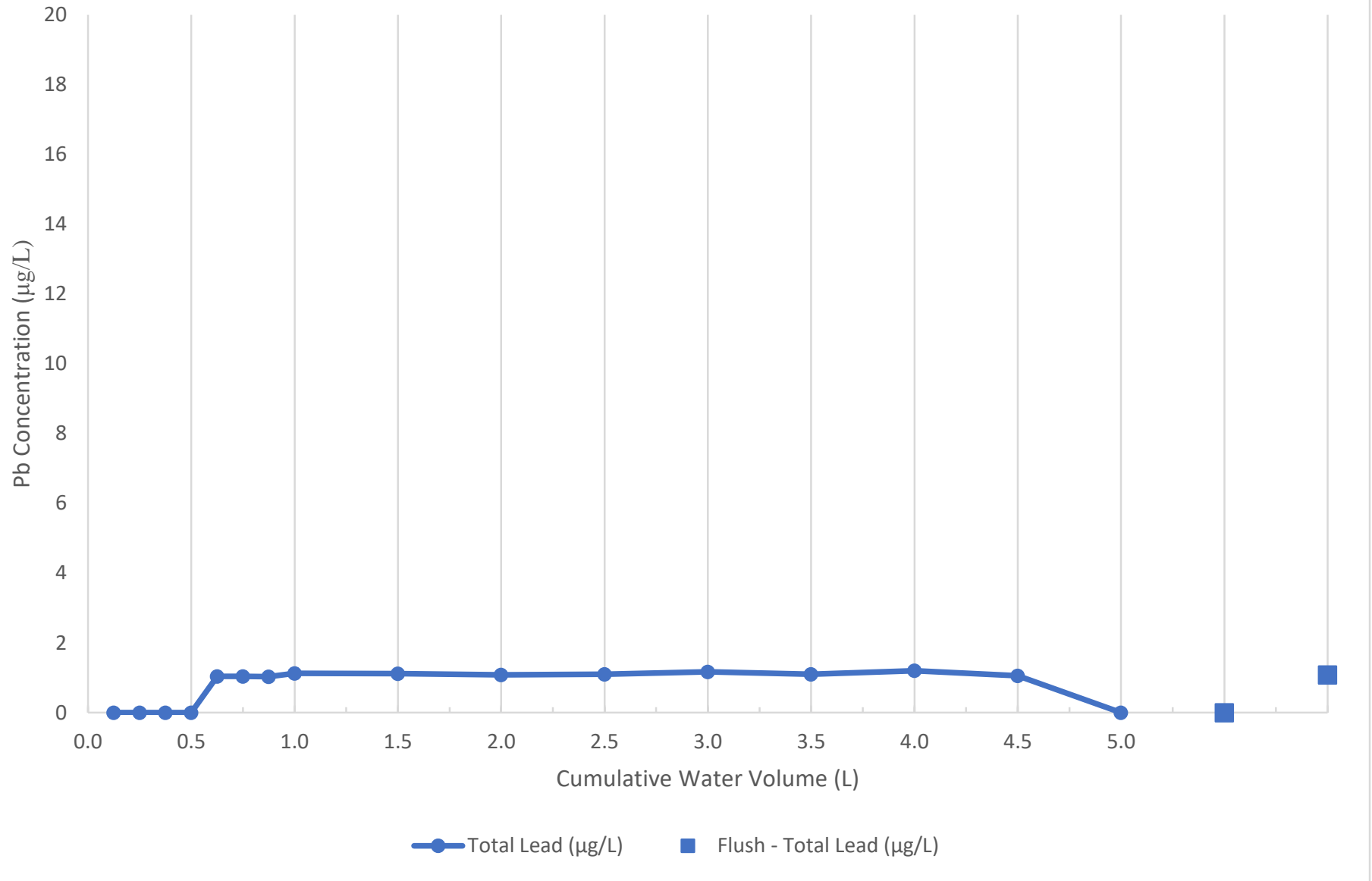


Table 1-1N
City of Newark Sequential Monitoring
Analytical Results
85 Astor St.

Site N - 4/16/19

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹	Free Cl ₂ ¹	Total Pb	Total Cu	Alkalinity	TAC (DW)	Anions (Sulfate, Chloride, Fluoride)	Orthophosphate	Silica	
					(degrees C)	(mg/L)	(µg/L)	(mg/L)	(mg/L as CaCO ₃)			(mg/L as P)	(mg/L as SiO ₂)	
N-0	500	N/A	Field Blank				0.00	0.00						Field Blank - Newark to Provide Type 1 Water
N-1	125	125	After Stagnation				0.00	19.90						Copper Piping (100%)
N-2	125	250	After Stagnation				0.00	4.17						Copper Piping (100%)
N-3	125	375	After Stagnation				0.00	3.50						Copper Piping (100%)
N-4	125	500	After Stagnation				0.00	2.88						Copper Piping (100%)
N-5	125	625	After Stagnation				1.04	2.50						Copper Piping (100%)
N-6	125	750	After Stagnation				1.04	2.09						Copper Piping (100%)
N-7	125	875	After Stagnation				1.03	1.83						Copper Piping (100%)
N-8	125	1000	After Stagnation				1.13	2.41						Copper Piping (100%)
N-9	500	1500	After Stagnation	7.8	13.8	0.93	1.12	1.78	27.20			0.52		Copper Piping (100%)
N-10	500	2000	After Stagnation				1.08	2.57						Copper Piping (100%)
N-11	500	2500	After Stagnation				1.10	2.27						Copper Piping (8%); Galvanized Piping (18%); Lead Piping (74%)
N-12	500	3000	After Stagnation				1.17	2.52						Lead Piping (100%)
N-13	500	3500	After Stagnation				1.10	2.27						Lead Piping (100%)
N-14	500	4000	After Stagnation				1.20	1.95						Lead Piping (100%)
N-15	500	4500	After Stagnation				1.06	1.83						Lead Piping (100%)
N-16	500	5000	After Stagnation				0.00	1.89						Lead Piping (13%); Water Main (87%)
N-17	500	5500	Flushed after the sequential sampling				0.00	1.74		See Table Below				Water Main (100%)
N-18	500	6000	Flushed after the sequential sampling				1.08	1.67			See Table Below			Water Main (100%)
N-19	500	6500	Flushed after the sequential sampling	7.78	13.6	0.89			24.60			0.52		Water Main (100%)

NOTES

1. pH, temperature, and free and total chlorine will be field measured.
2. **HOMEOWNER SHOULD FLUSH THE LINE FOR 10 MINUTES BEFORE BEGINNING STAGNATION PERIOD (i.e. night before sampling).**

Table 1-1N
City of Newark Sequential Monitoring
Analytical Results
85 Astor St.

Site N - 4/16/19

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹	Free Cl ₂ ¹	Total Pb	Total Cu	Alkalinity	TAC (DW)	Anions (Sulfate, Chloride, Fluoride)	Orthophosphate	Silica	
					(degrees C)	(mg/L)	(µg/L)	(mg/L)	(mg/L as CaCO ₃)			(mg/L as P)	(mg/L as SiO ₂)	

P-31 TAC (DW)		Units
Calcium	10700	µg/L
Iron	0	µg/L
Magnesium	2850	µg/L
Potassium	818	µg/L
Sodium	24500	µg/L
Aluminum	45.1	µg/L
Antimony	0	µg/L
Arsenic	0	µg/L
Barium	7.06	µg/L
Beryllium	0	µg/L
Cadmium	0	µg/L
Chromium	0	µg/L
Cobalt	0	µg/L
Manganese	3.89	µg/L
Molybdenum	0	µg/L
Nickel	0	µg/L
Selenium	0	µg/L
Silver	0	µg/L
Thallium	0	µg/L
Vanadium	0	µg/L
Zinc	2.81	µg/L

P-32 Anions		Units
Chloride	48	mg/L
Fluoride	0	mg/L
Sulfate	6.8	mg/L



**Gouges from cable tool
extraction of LSL**



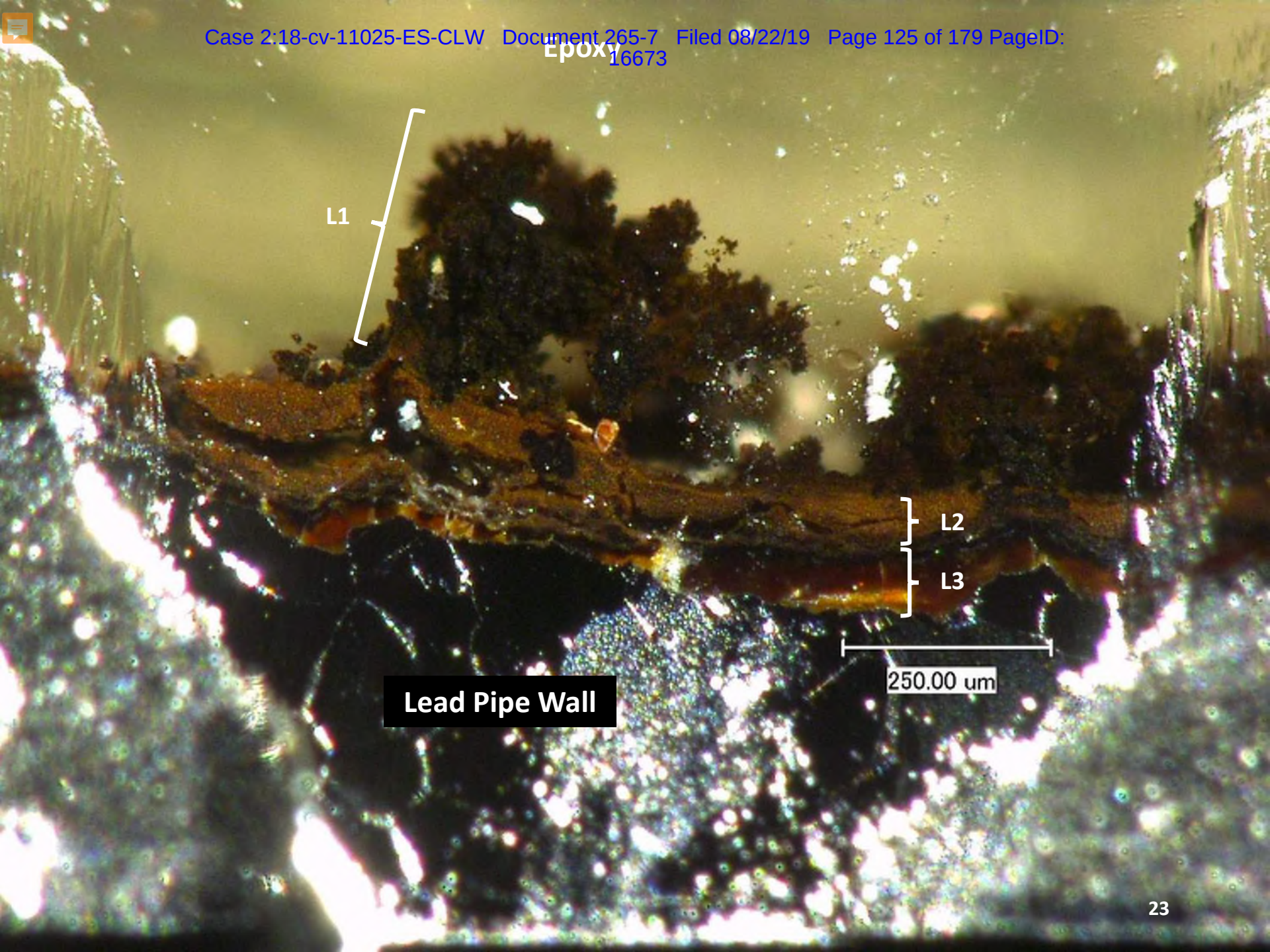


Area of intact scale, cross-sectioned and analyzed with SEM/EDS.

Pinkish white material ('nacreous layer'), secondarily formed over areas disrupted by cable tool.

Area of scale harvested and analyzed by XRD (slightly disrupted layer L1 visible here, layers L2 and L3 not visible).





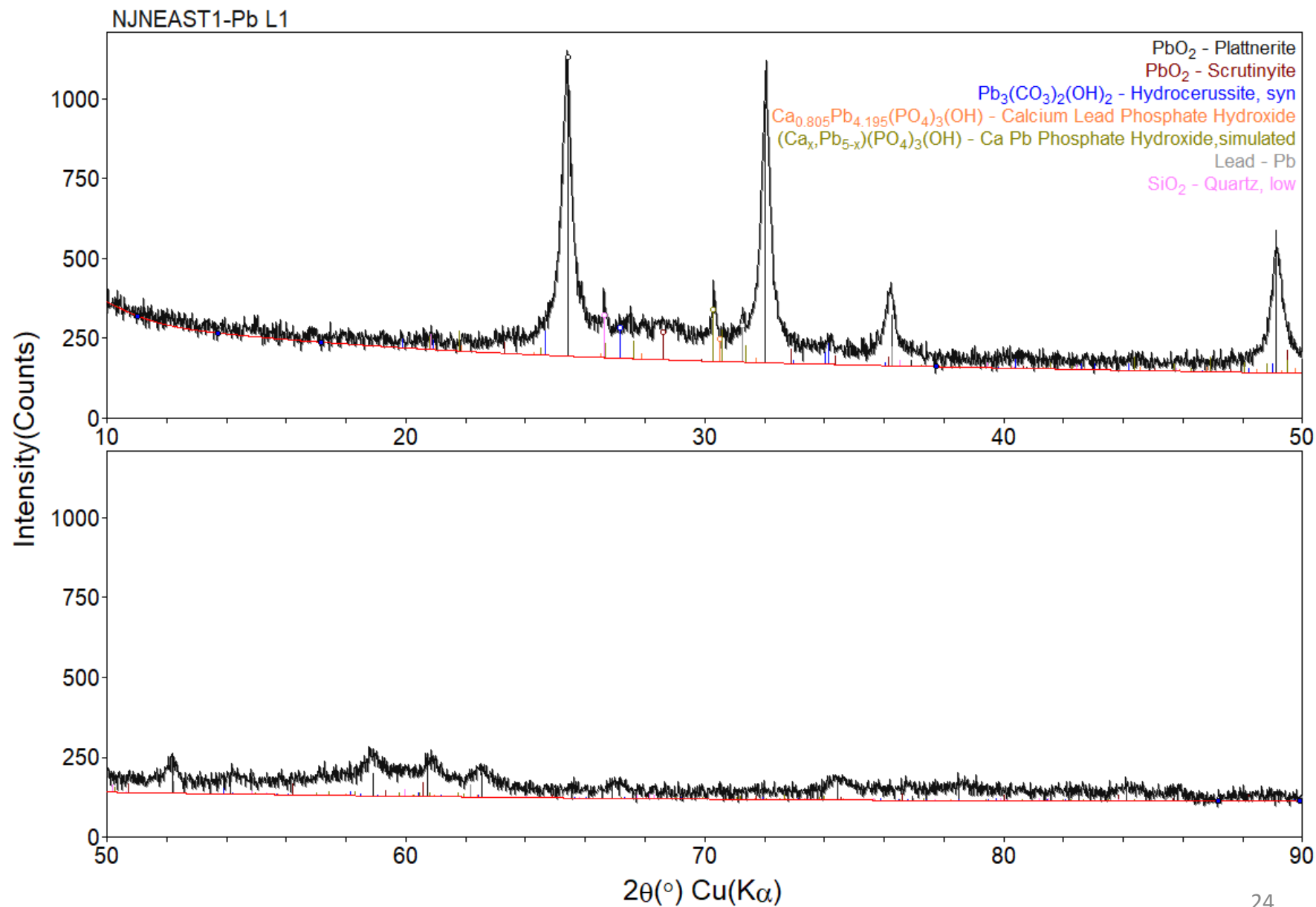
L1

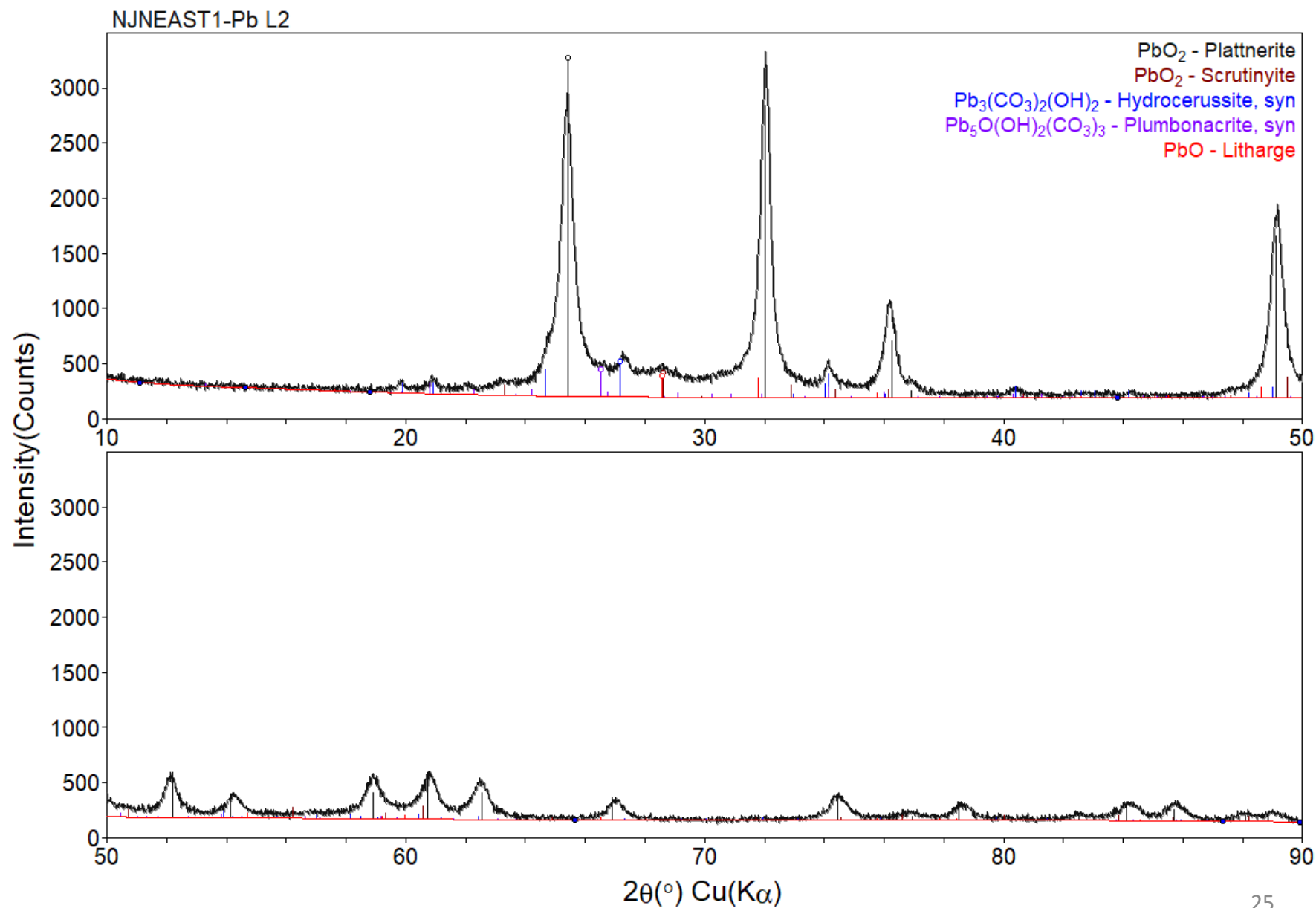
L2

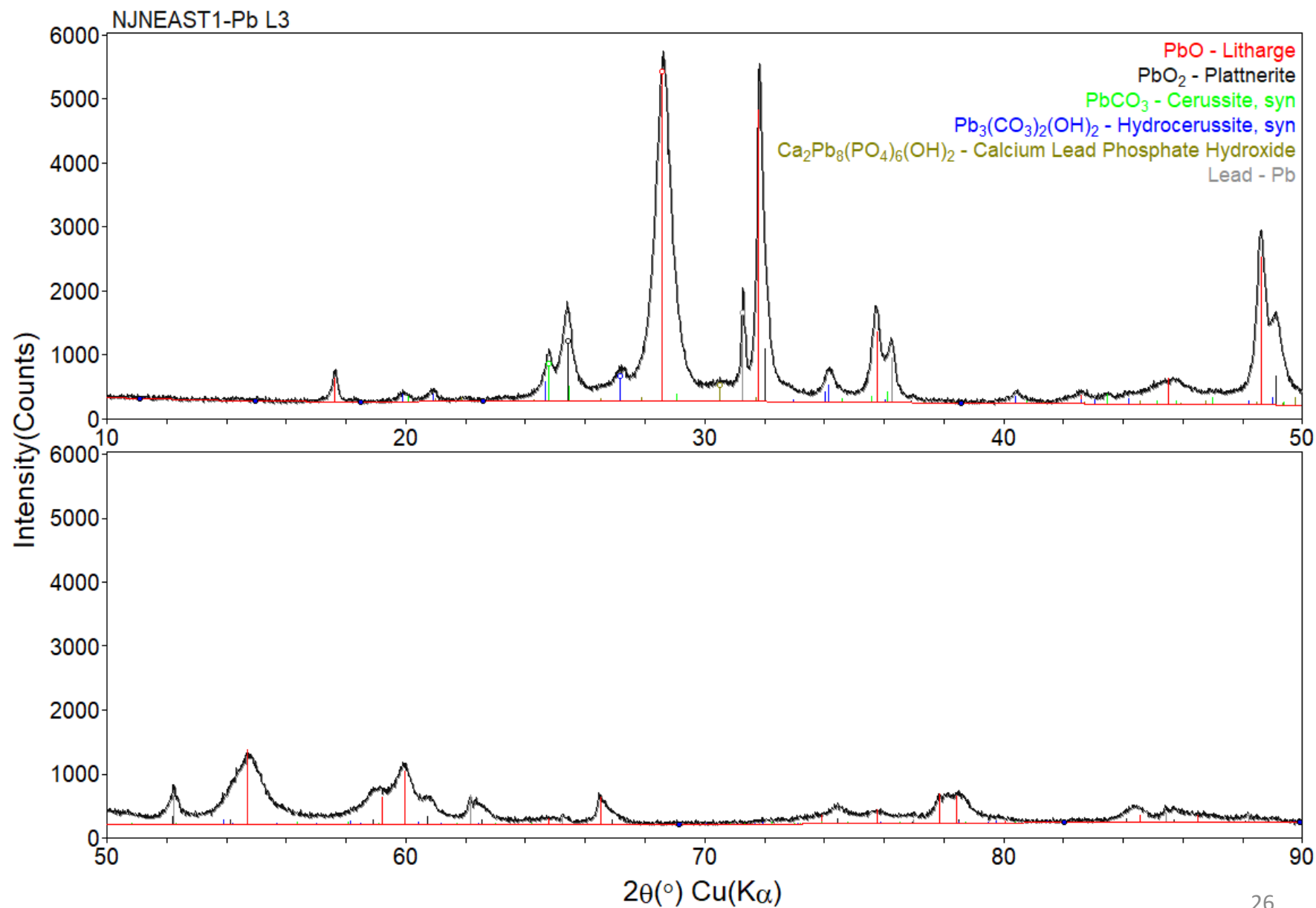
L3

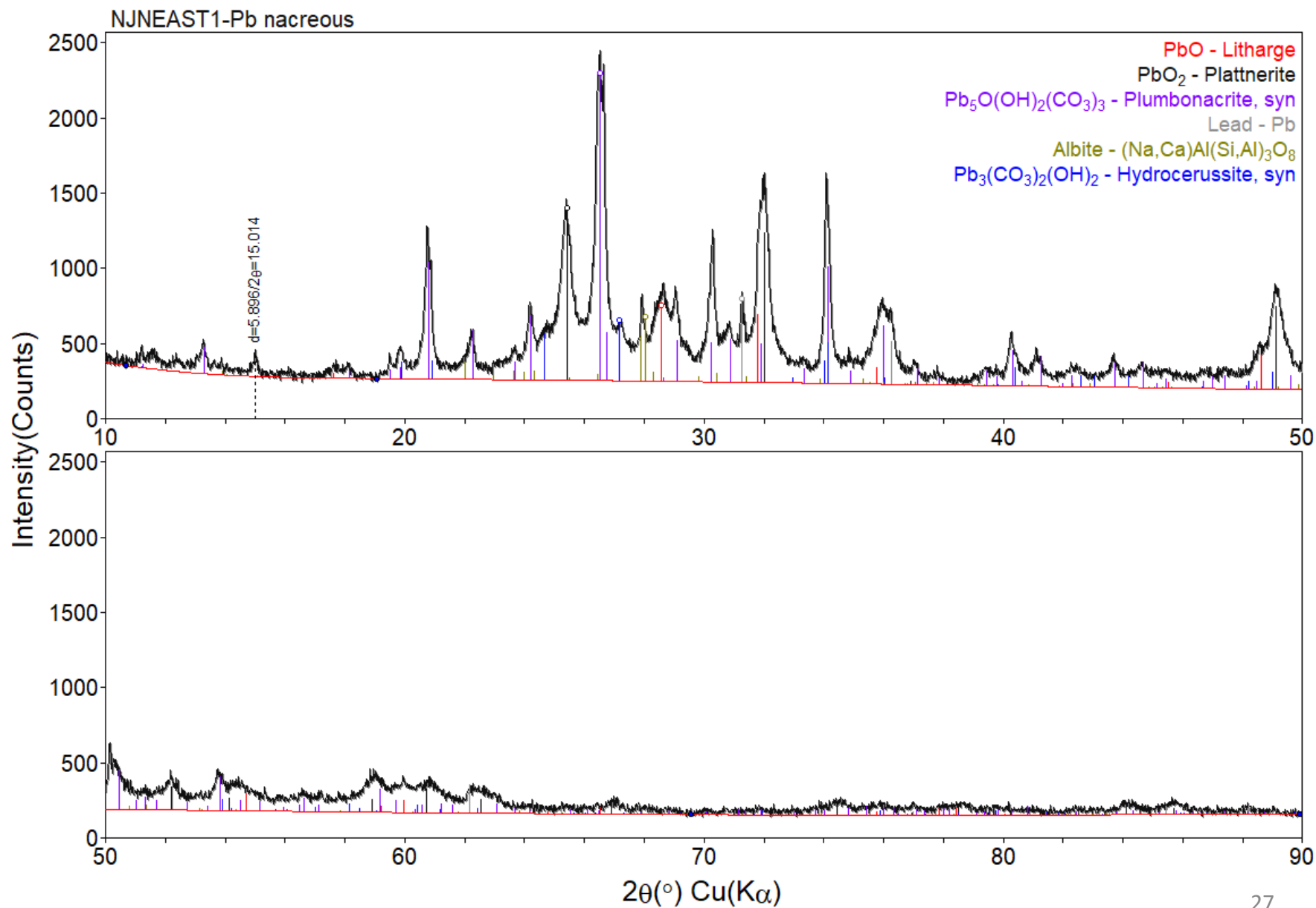
Lead Pipe Wall

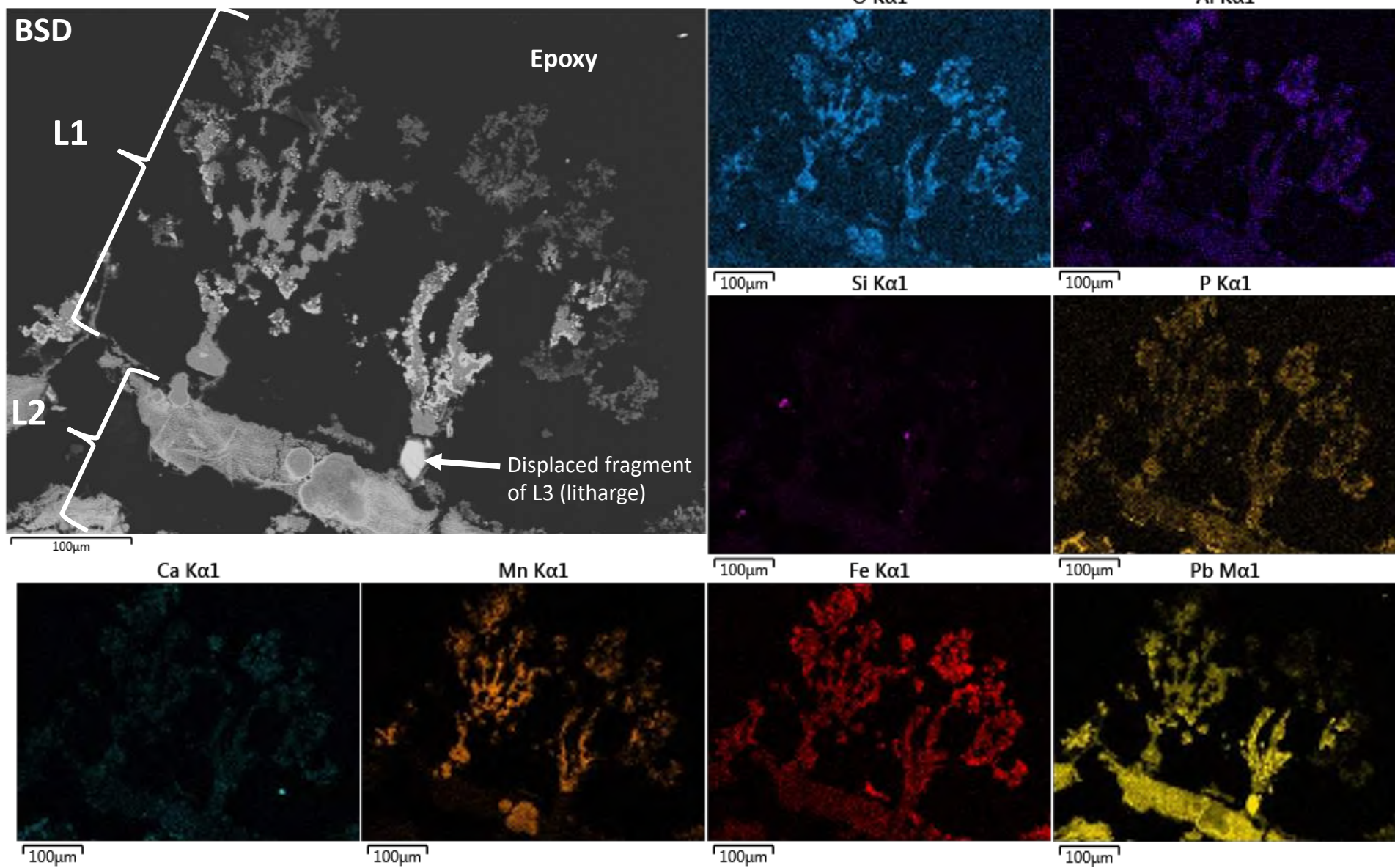
250.00 um











Base of Mn
dendrite with
internal trace of
plattnerite texture

Epoxy

L1

L2

L3

Lead Pipe Wall

50µm

Al Kα1

P Kα1

Ca Kα1

Pb Mα1

Fe Kα1

Mn Kα1

50µm

50µm

50µm

50µm

50µm

50µm

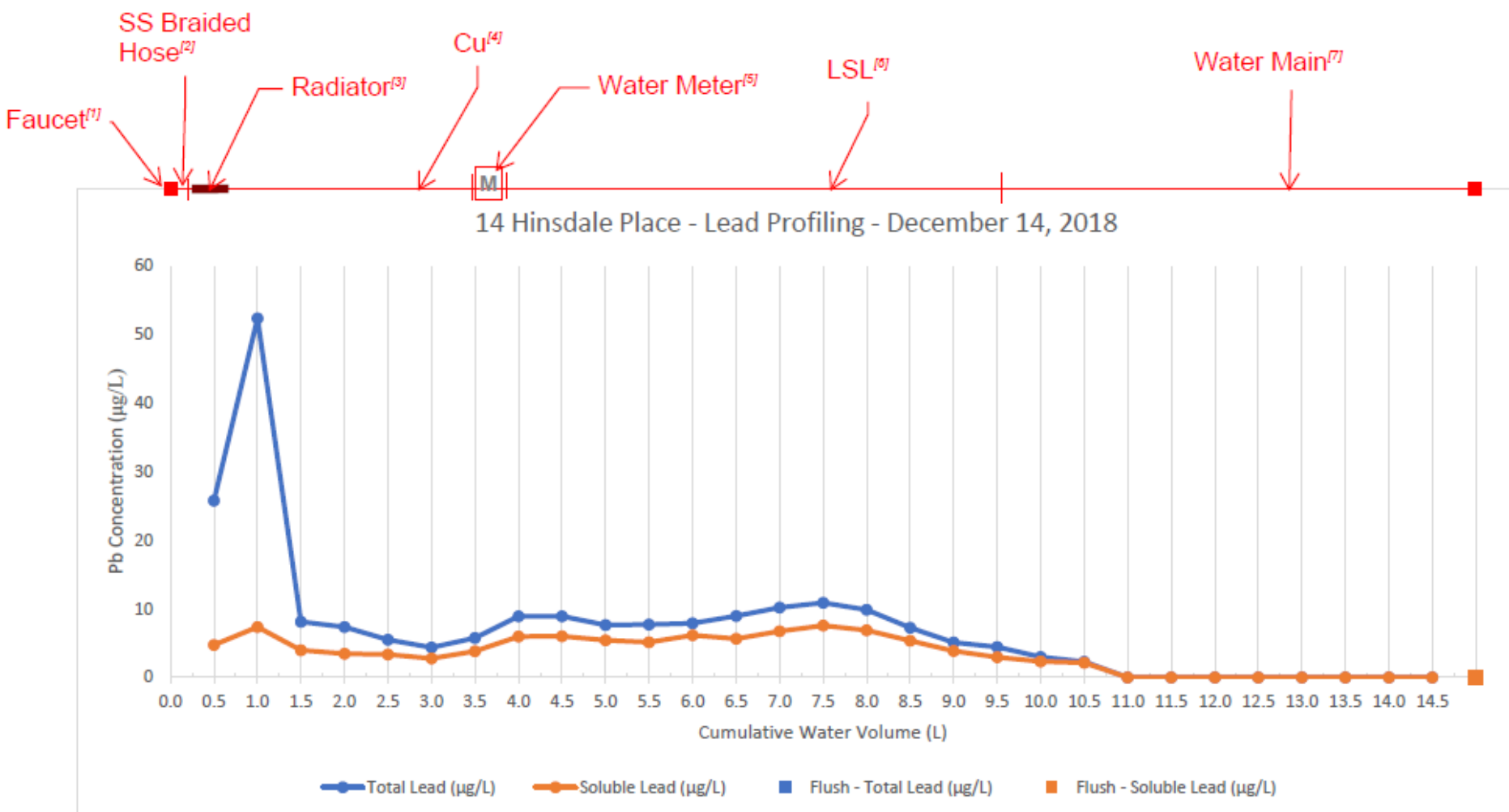
Newark, NJ

LSL samples extracted December 20, 2018

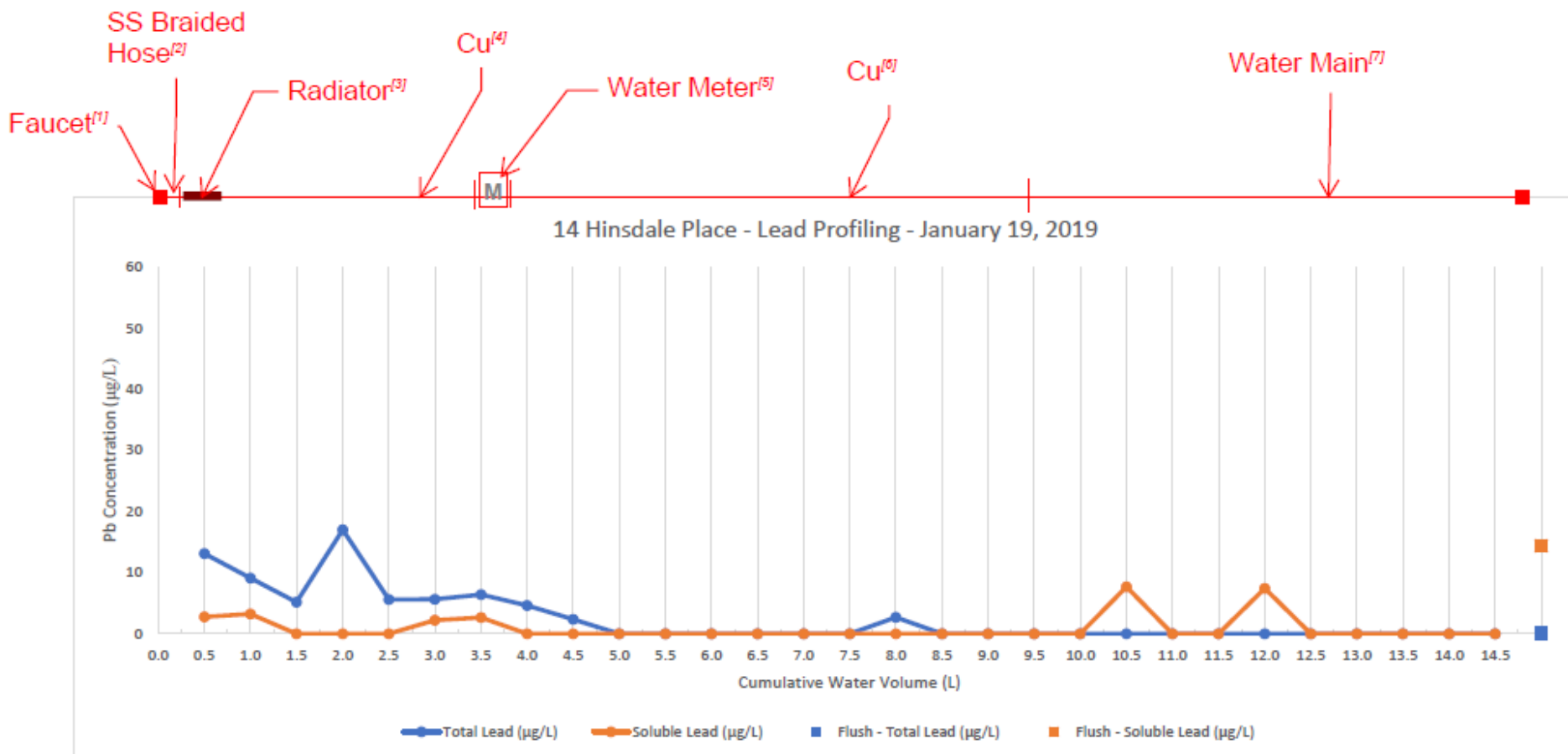
Report from:

Advanced Materials and Solids Analysis Research Core

Cincinnati, OH



Before LSL replacement



After LSL replacement



Newark, NJ
Lead Service Line
Address: 14 Hinsdale Pl.
Installed: 1910
Removed: December 20, 2018



11/11/18

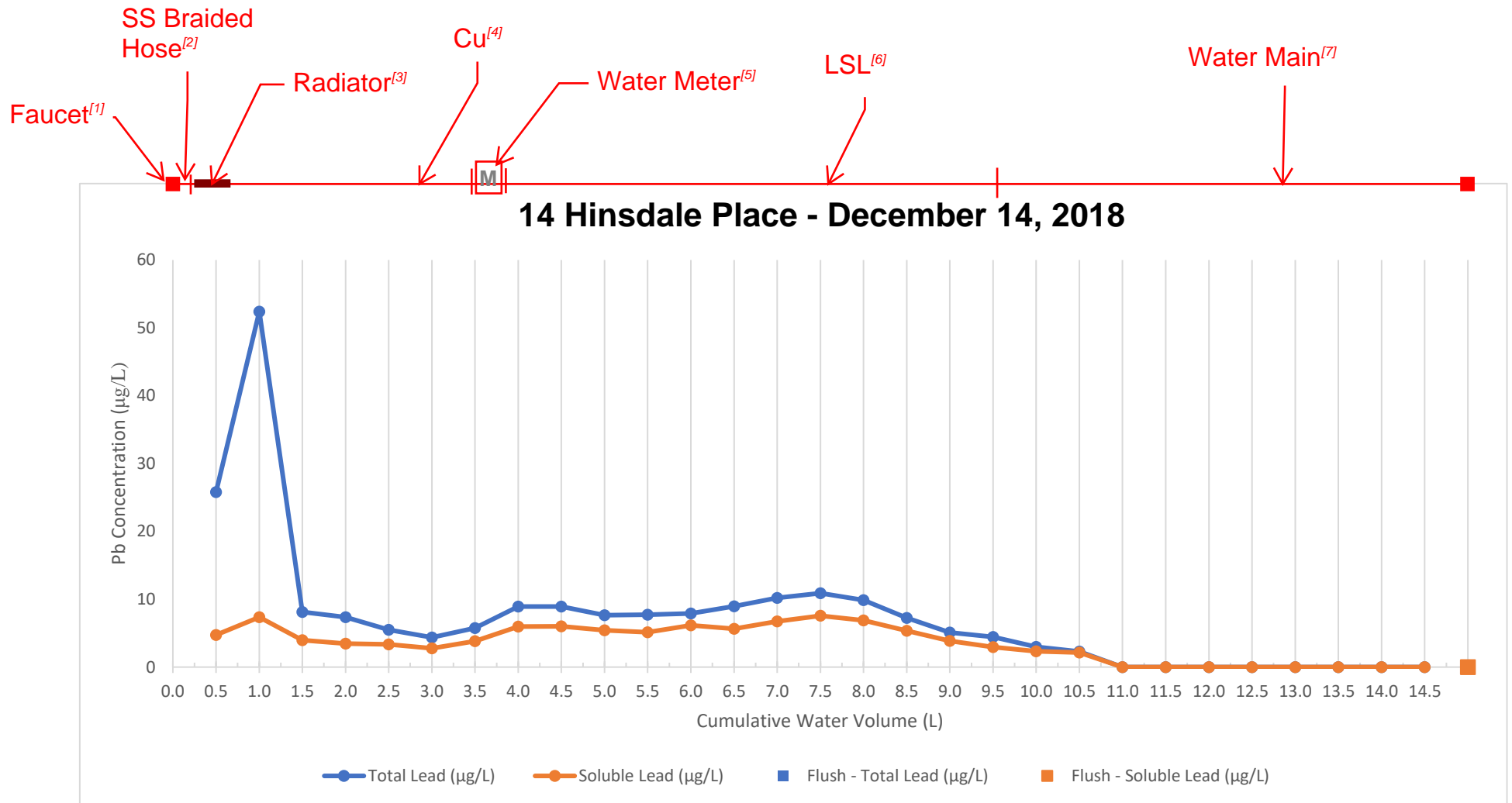


Table 1-1C
City of Newark Sequential Monitoring
Analytical Results
14 Hinsdale

Site C - 12/14/18

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹	Free Cl ₂ ¹	Total Pb	Dissolved Pb	Total Cu	Alk.	Cond.	Othophosphate	Silica	
					(degrees C)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(mg/L as CaCO ₃)	umhos/cm	(mg/L as P)	(mg/L as SiO ₂)	
C1	500	500	After Stagnation	N/A	N/A	N/A	25.8	4.72	0.26	42.0	225	<.100		Faucet (13% SS Flex) and Copper Piping with Lead Solder (87%)
C2	500	1000	After Stagnation				52.4	7.35	0.296			<.100	6.41	Copper Piping with Lead Solder (100%)
C3	500	1500	After Stagnation				8.11	3.95	0.182			<.100		Copper Piping with Lead Solder (100%)
C4	500	2000	After Stagnation				7.34	3.44	0.187			<.100		Copper Piping with Lead Solder (100%)
C5	500	2500	After Stagnation				5.49	3.34	0.17			<.100		Copper Piping with Lead Solder (100%)
C6	500	3000	After Stagnation				4.37	2.75	0.149			<.100		Copper Piping with Lead Solder (100%)
C7	500	3500	After Stagnation				5.75	3.83	0.12			<.100		Copper Piping with Lead Solder (100%)
C8	500	4000	After Stagnation				8.91	5.96	0.0692			<.100		Copper Piping (100%); Lead Piping (70%)
C9	500	4500	After Stagnation				8.91	5.99	<.05			<.100		Lead Piping (100%)
C10	500	5000	After Stagnation				7.65	5.44	<.05			<.100		Lead Piping (100%)
C11	500	5500	After Stagnation				7.73	5.13	<.05			<.100		Lead Piping (100%)
C12	500	6000	After Stagnation				7.9	6.16	<.05			<.100		Lead Piping (100%)
C13	500	6500	After Stagnation				8.97	5.66	<.05			<.100		Lead Piping (100%)
C14	500	7000	After Stagnation				10.2	6.73	<.05			<.100		Lead Piping (100%)
C15	500	7500	After Stagnation				10.9	7.56	<.05			<.100		Lead Piping (100%)
C16	500	8000	After Stagnation	N/A	N/A	N/A	9.88	6.87	<.05			<.100		Lead Piping (100%)
C17	500	8500	After Stagnation				7.23	5.36	<.05	28.0	210	<.100	6.48	Lead Piping (100%)
C18	500	9000	After Stagnation				5.08	3.87	<.05			<.100		Lead Piping (100%)
C19	500	9500	After Stagnation				4.43	2.96	<.05			<.100		Lead Piping (100%)
C20	500	10000	After Stagnation				3.00	2.34	<.05			<.100		Lead Piping (11%); Water Main (89%)
C21	500	10500	After Stagnation				2.30	2.15	<.05			<.100		Water Main (100%)
C22	500	11000	After Stagnation				2.04	<2.00	<.05			<.100		Water Main (100%)
C23	500	11500	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)
C24	500	12000	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)
C25	500	12500	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)
C26	500	13000	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)
C27	500	13500	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)

Table 1-1C
City of Newark Sequential Monitoring
Analytical Results
14 Hinsdale

Site C - 12/14/18

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹	Free Cl ₂ ¹	Total Pb	Dissolved Pb	Total Cu	Alk.	Cond.	Othophosphate	Silica	
					(degrees C)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(mg/L as CaCO ₃)	umhos/cm	(mg/L as P)	(mg/L as SiO2)	
C28	500	14000	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)
C29	500	14500	After Stagnation				<2.00	<2.00	<.05			<.100		Water Main (100%)
C30FLUSH	500	15000	Flushed after the sequential sampling	N/A	N/A	N/A	<2.00	<2.00	<.05	28.0	214	<.100	6.57	Water Main (100%)

NOTES

1. pH, temperature, and free and total chlorine will be field measured.

2. **HOMEOWNER SHOULD FLUSH THE LINE FOR 10 MINUTES BEFORE BEGINNING STAGNATION PERIOD (i.e. night before sampling).**

TIME OF FLUSH / START OF STAGNATION PERIOD SHOULD BE RECORDED

Table 1-1K
City of Newark Sequential Monitoring
Analytical Results
14 Hinsdale
After Lead Service Line Replacement

Site K - 1/19/19

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹	Free Cl ₂ ¹	Total Pb	Dissolved Pb	Total Cu	Alk.	Cond.	Othophosphate	Silica	
					(degrees C)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(mg/L as CaCO ₃)	umhos/cm	(mg/L as P)	(mg/L as SiO ₂)	
K1	500	500	After Stagnation	6.76	15.1	0.06	13.1	2.78	0.586	27.0	214			Faucet (13% SS Flex) and Copper Piping with Lead Solder (87%)
K2	500	1000	After Stagnation				9.11	3.23	0.531			<.1		Copper Piping with Lead Solder (100%)
K3	500	1500	After Stagnation				5.18	<2	0.522					Copper Piping with Lead Solder (100%)
K4	500	2000	After Stagnation				17	<2	0.59					Copper Piping with Lead Solder (100%)
K5	500	2500	After Stagnation				5.6	<2	0.556					Copper Piping with Lead Solder (100%)
K6	500	3000	After Stagnation				5.64	2.23	0.579					Copper Piping with Lead Solder (100%)
K7	500	3500	After Stagnation				6.39	2.67	0.664					Copper Piping with Lead Solder (100%)
K8	500	4000	After Stagnation				4.61	<2	1.22					Copper Piping (100%); Lead Piping (70%)
K9	500	4500	After Stagnation				2.38	<2	1.6					Lead Piping (100%)
K10	500	5000	After Stagnation				<2	<2	1.65					Lead Piping (100%)
K11	500	5500	After Stagnation				<2	<2	1.62					Lead Piping (100%)
K12	500	6000	After Stagnation				<2	<2	1.6					Lead Piping (100%)
K13	500	6500	After Stagnation				<2	<2	1.6					Lead Piping (100%)
K14	500	7000	After Stagnation				<2	<2	1.58					Lead Piping (100%)
K15	500	7500	After Stagnation				<2	<2	1.56					Lead Piping (100%)
K16	500	8000	After Stagnation	6.9	9.9	0.03	2.69	<2	1.48	31.0	202			Lead Piping (100%)
K17	500	8500	After Stagnation				<2	<2	1.53			<.1		Lead Piping (100%)
K18	500	9000	After Stagnation				<2	<2	1.51					Lead Piping (100%)
K19	500	9500	After Stagnation				<2	<2	1.46					Lead Piping (100%)
K20	500	10000	After Stagnation				<2	<2	1.19					Lead Piping (11%); Water Main (89%)
K21	500	10500	After Stagnation				<2	7.68	0.763					Water Main (100%)
K22	500	11000	After Stagnation				<2	<2	0.439					Water Main (100%)
K23	500	11500	After Stagnation				<2	<2	0.277					Water Main (100%)
K24	500	12000	After Stagnation				<2	7.44	0.192					Water Main (100%)
K25	500	12500	After Stagnation				<2	<2	0.15					Water Main (100%)
K26	500	13000	After Stagnation				<2	<2	0.131					Water Main (100%)
K27	500	13500	After Stagnation				<2	<2	0.127					Water Main (100%)

Table 1-1K
City of Newark Sequential Monitoring
Analytical Results
14 Hinsdale
After Lead Service Line Replacement

Site K - 1/19/19

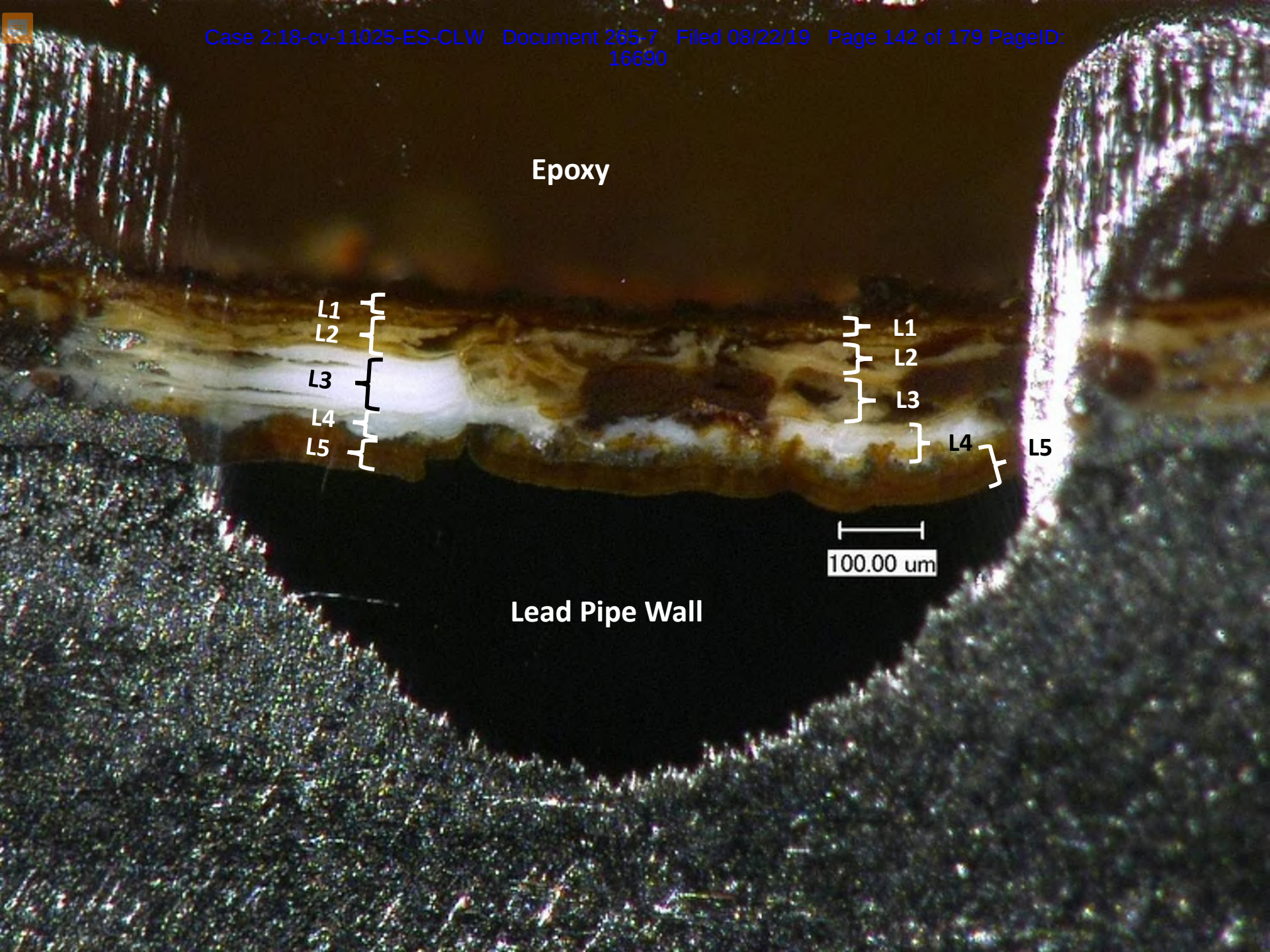
Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹	Free Cl ₂ ¹	Total Pb	Dissolved Pb	Total Cu	Alk.	Cond.	Othophosphate	Silica	
					(degrees C)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(mg/L as CaCO ₃)	umhos/cm	(mg/L as P)	(mg/L as SiO2)	
K28	500	14000	After Stagnation				<2	<2	0.113					Water Main (100%)
K29	500	14500	After Stagnation				<2	<2	0.11					Water Main (100%)
K30 FLUSH	500	15000	Flushed after the sequential sampling	6.82	8.9	0.98	<2	14.4	0.0646	30.0	211	0.702		Water Main (100%)

NOTES

1. pH, temperature, and free and total chlorine will be field measured.

2. **HOMEOWNER SHOULD FLUSH THE LINE FOR 10 MINUTES BEFORE BEGINNING STAGNATION PERIOD (i.e. night before sampling).**

TIME OF FLUSH / START OF STAGNATION PERIOD SHOULD BE RECORDED



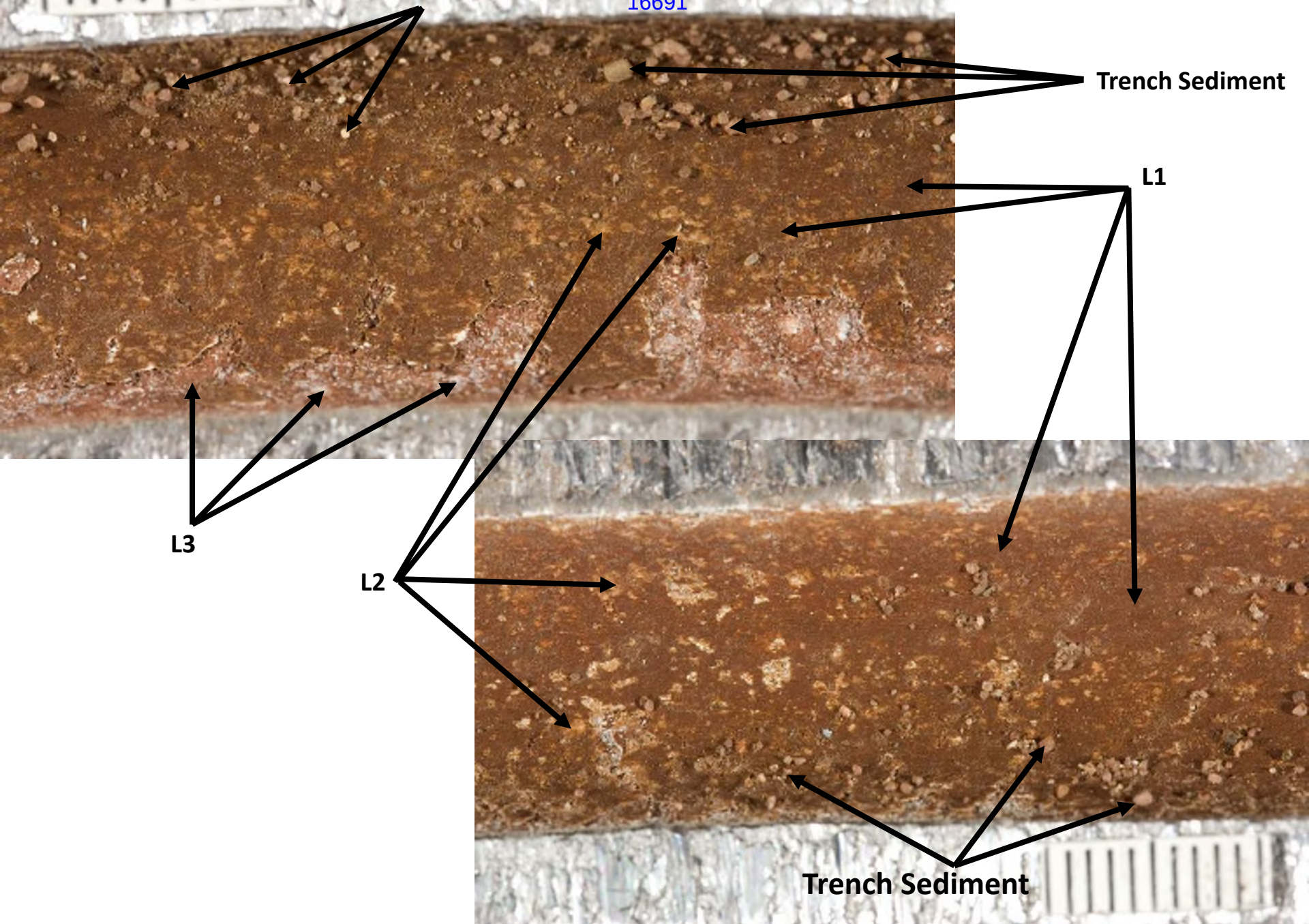
Epoxy

L1
L2
L3
L4
L5

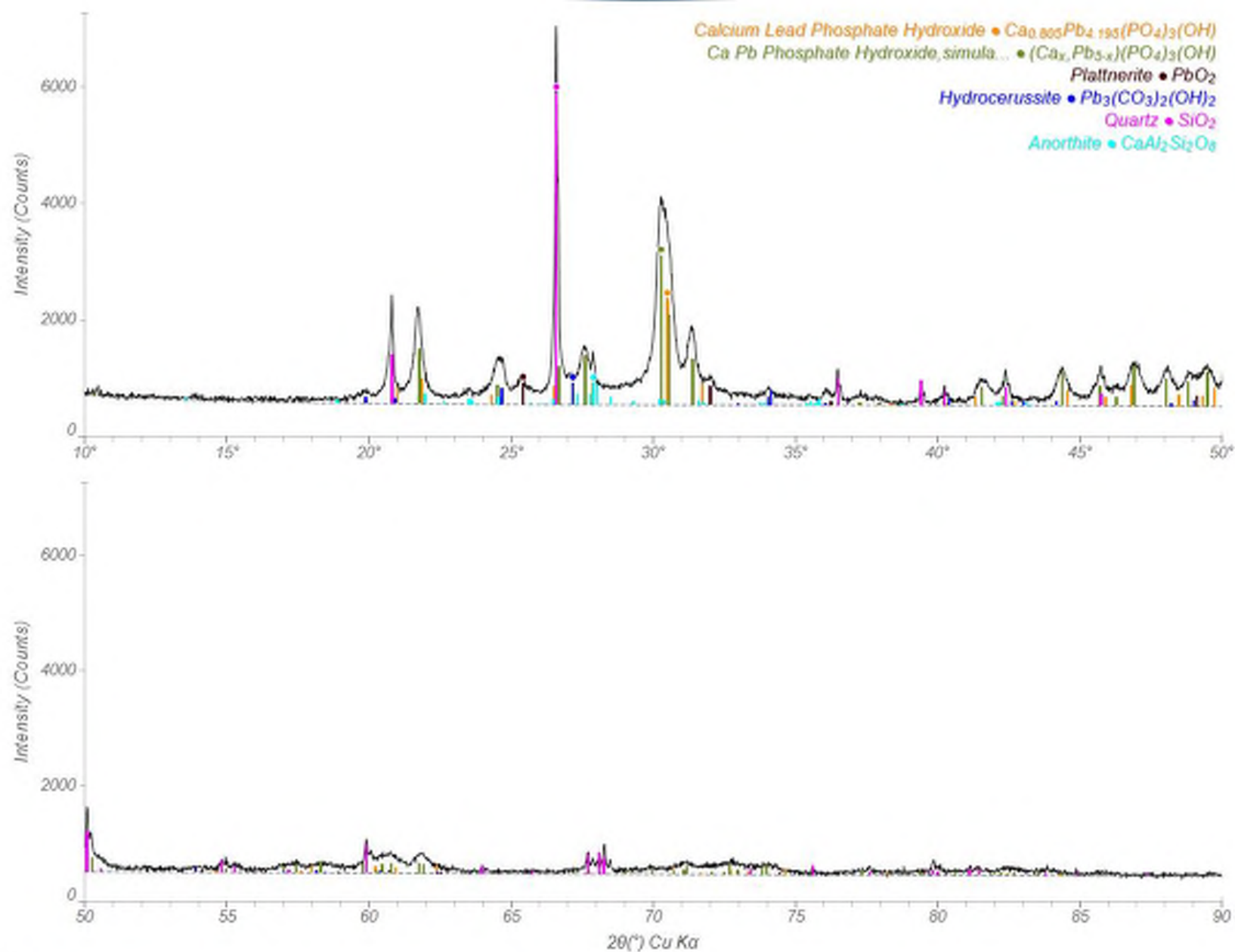
L1
L2
L3
L4
L5

100.00 um

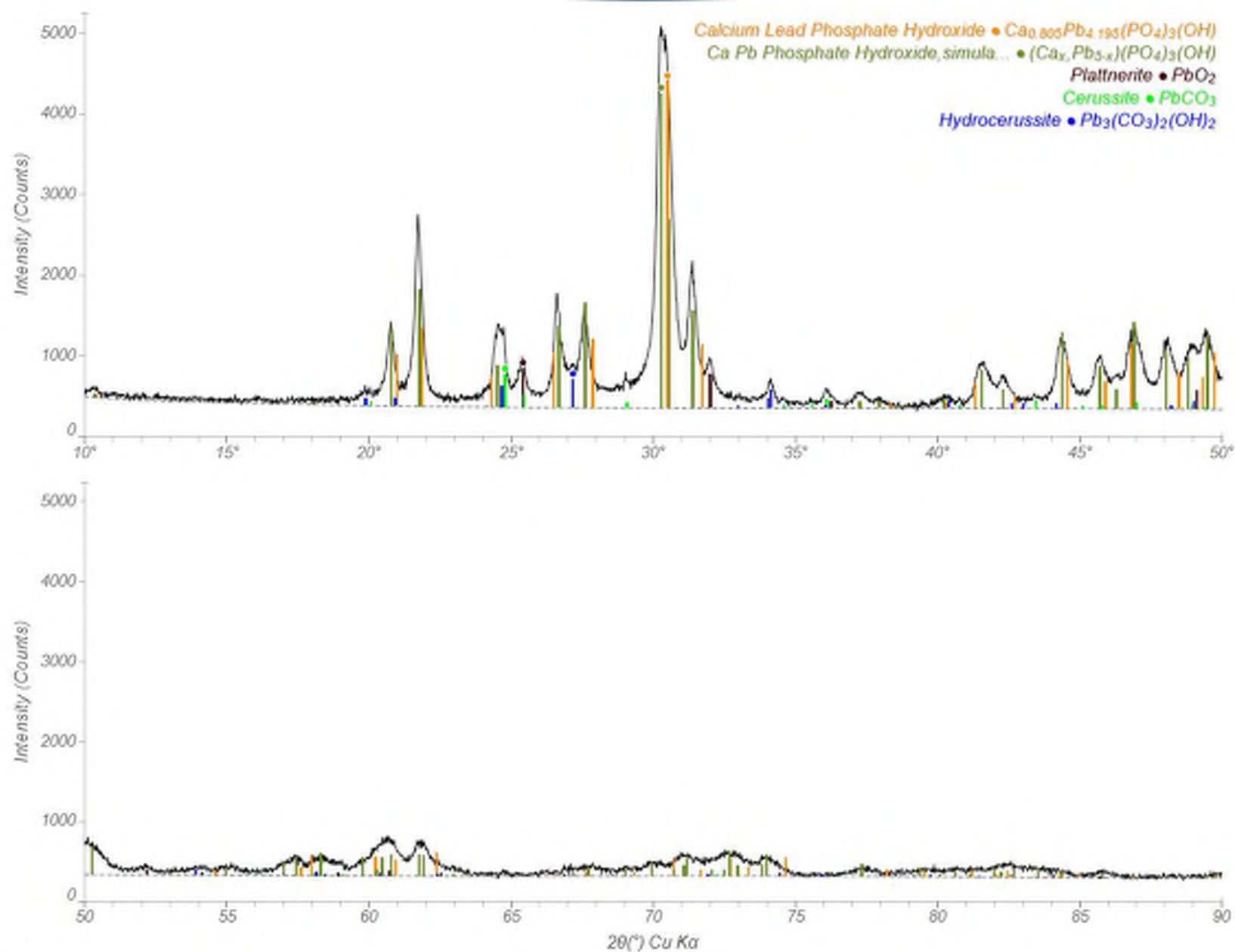
Lead Pipe Wall

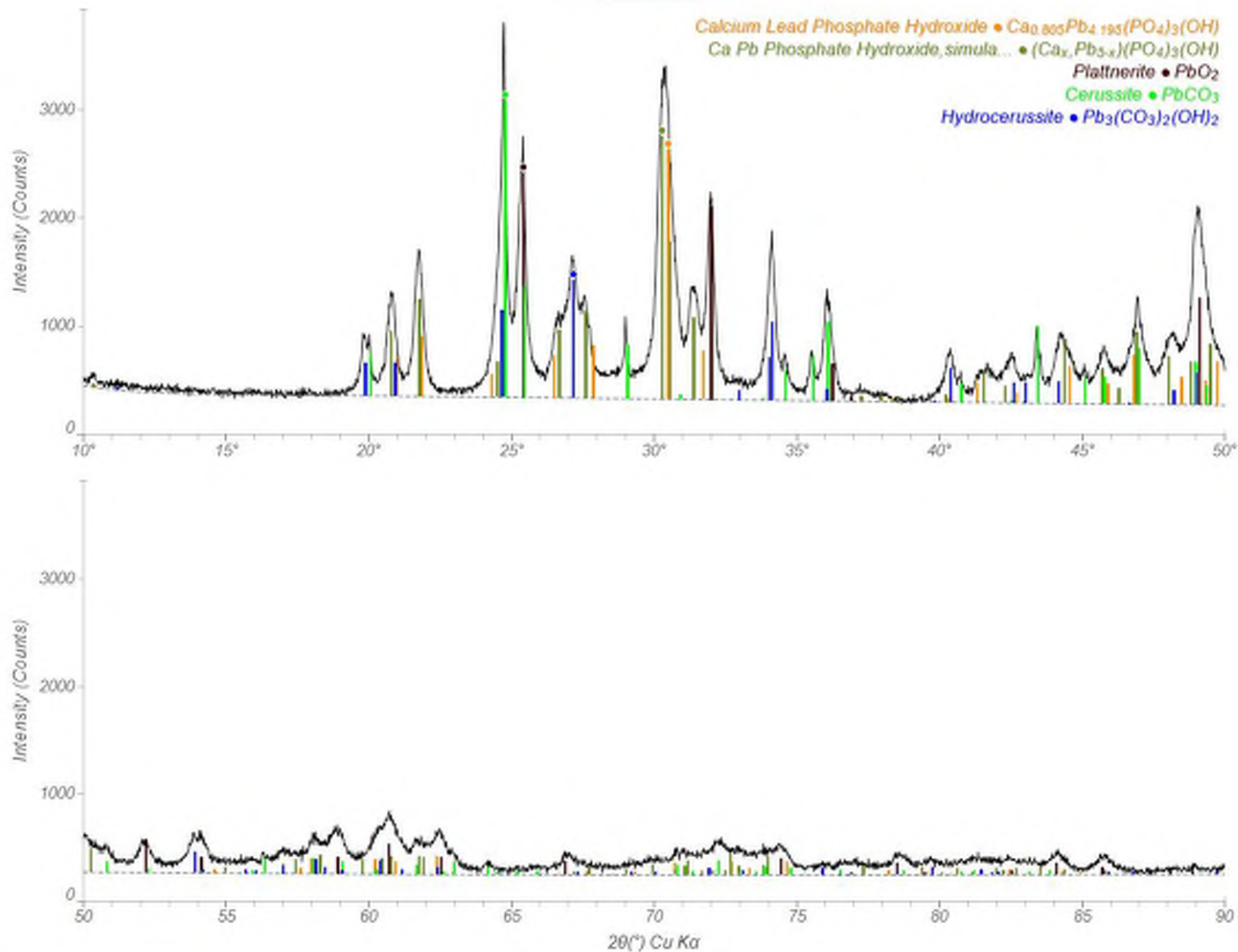


NJINCHN1-Pb L1

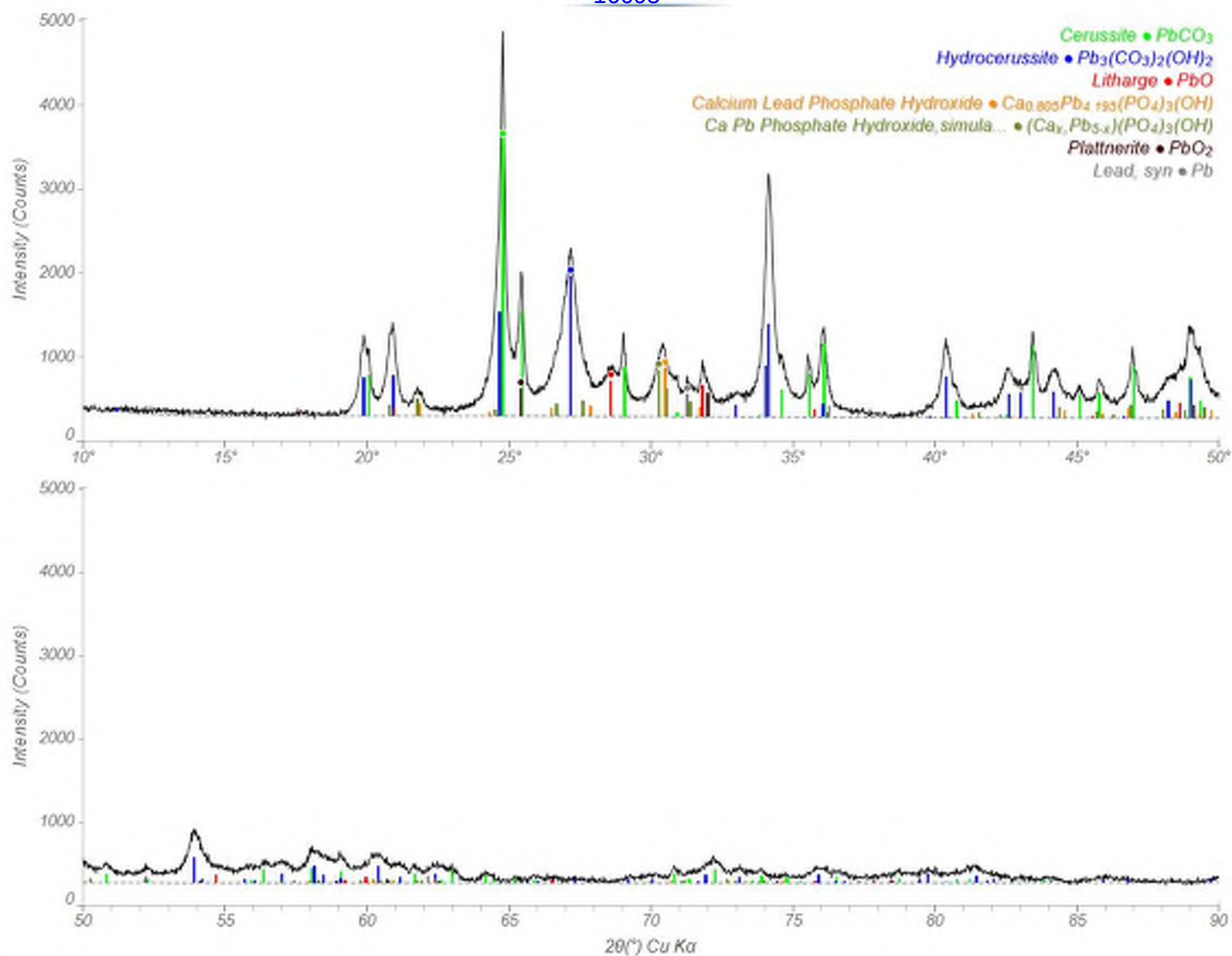


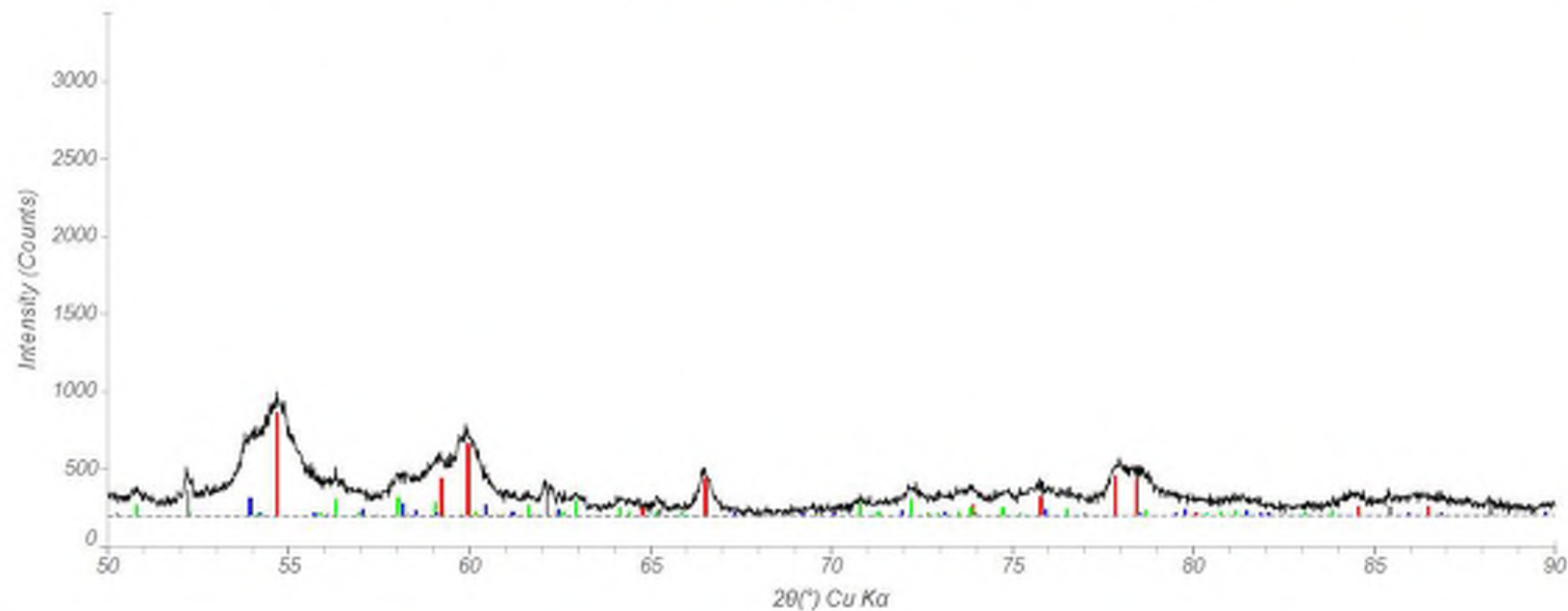
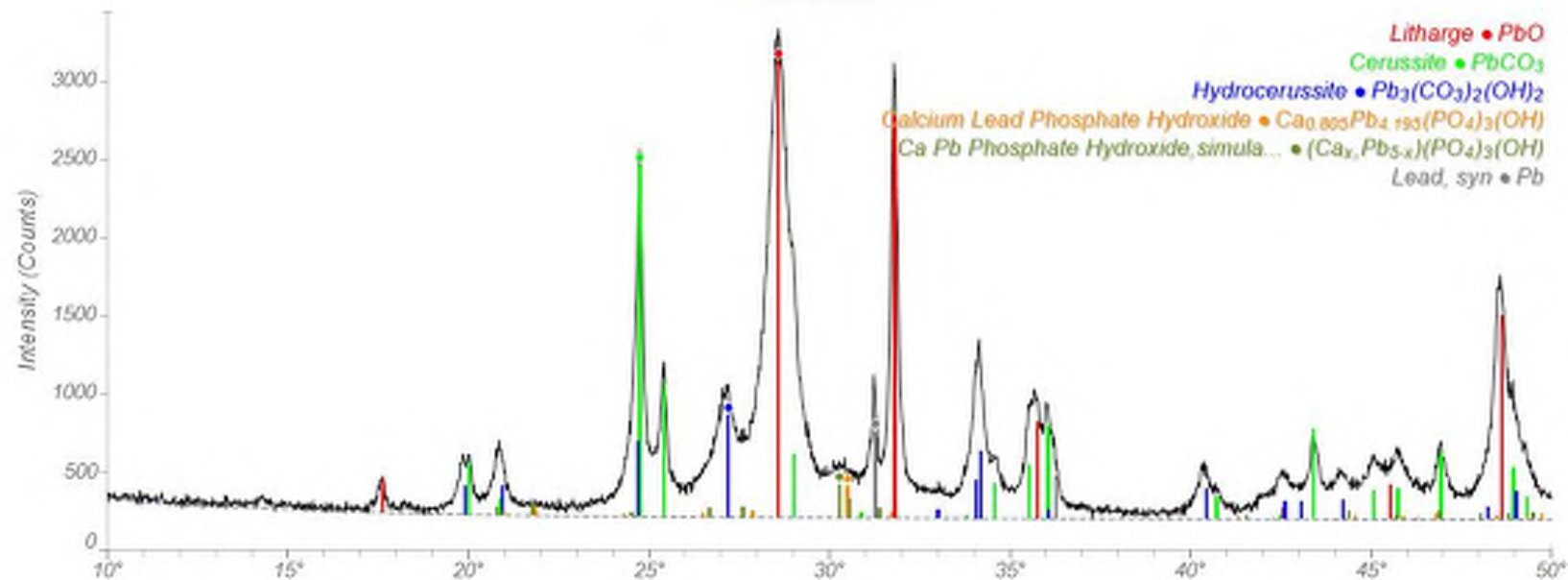
NINEH1-Pb L2



NJNENH1 Pb L3-L4
16694

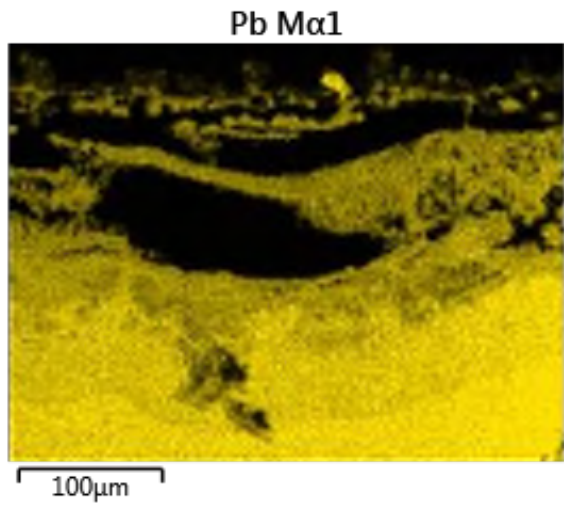
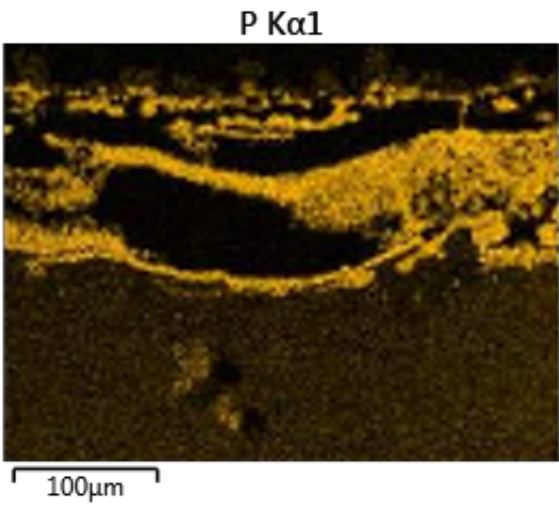
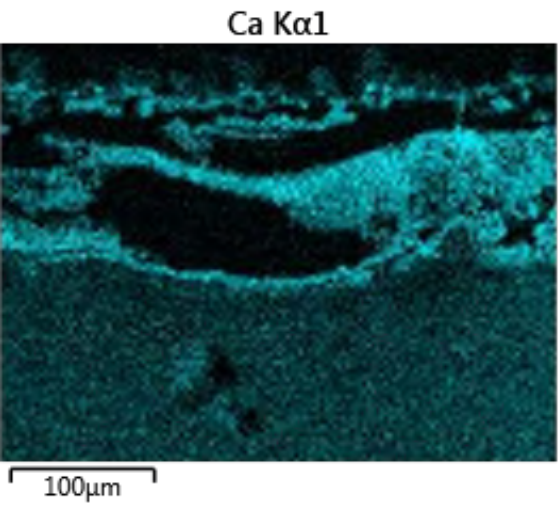
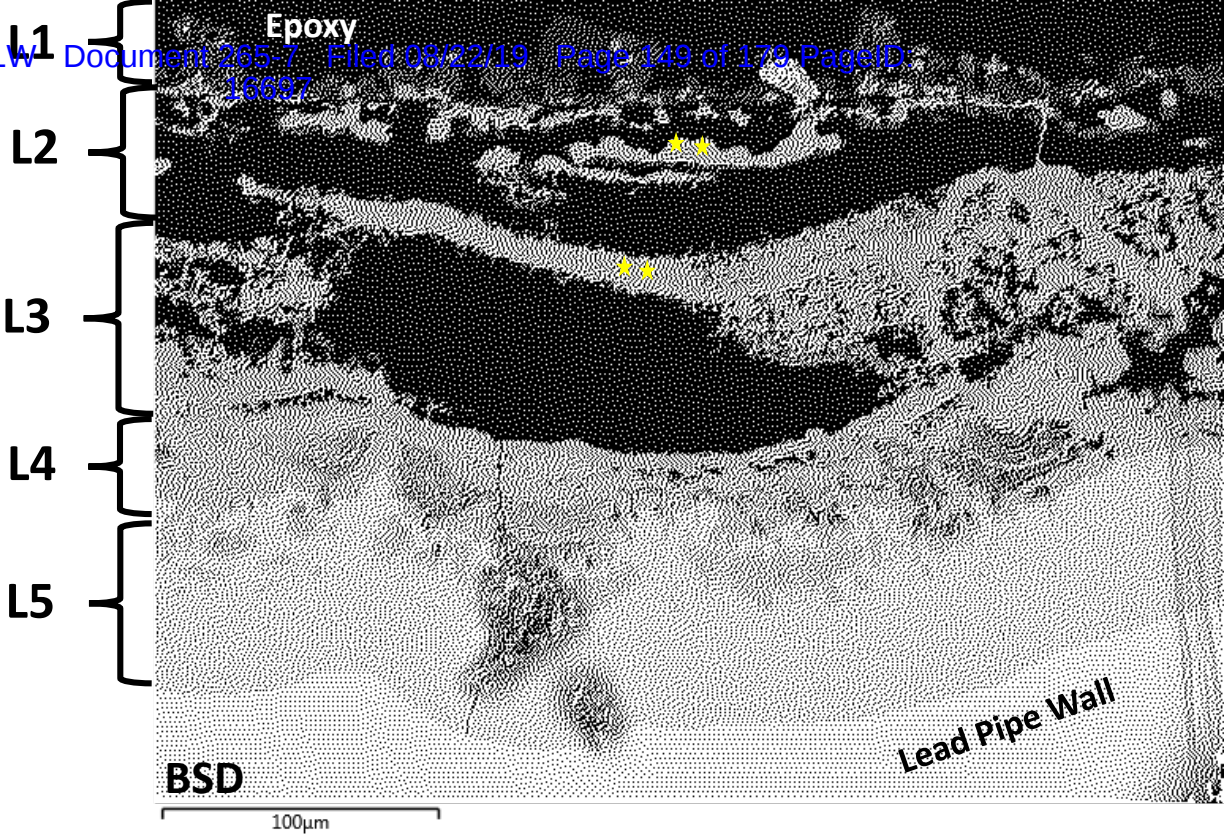
16695

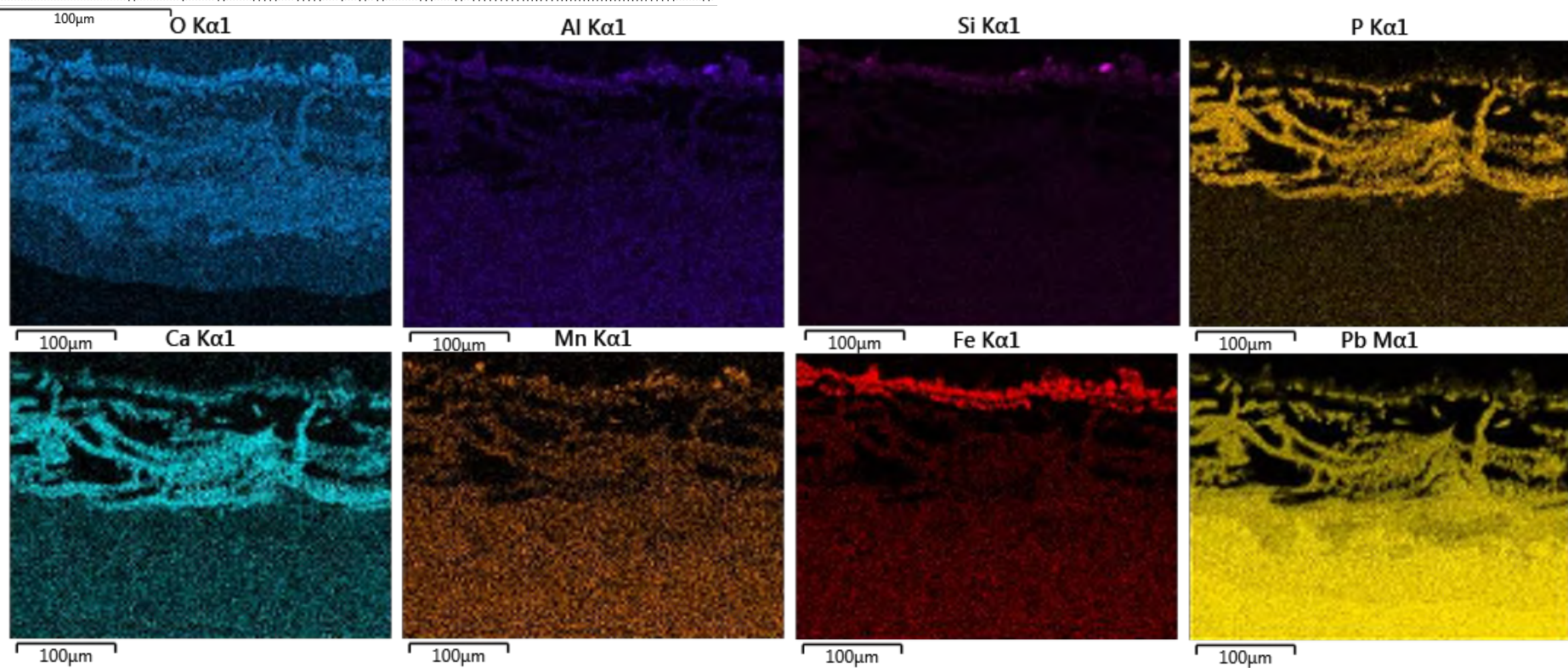


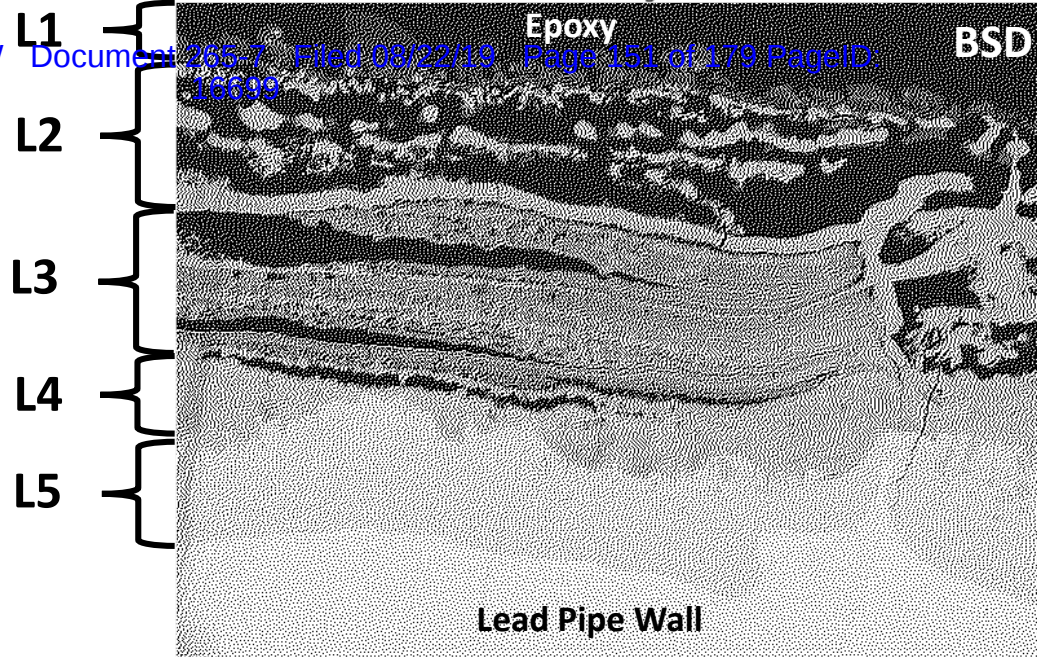
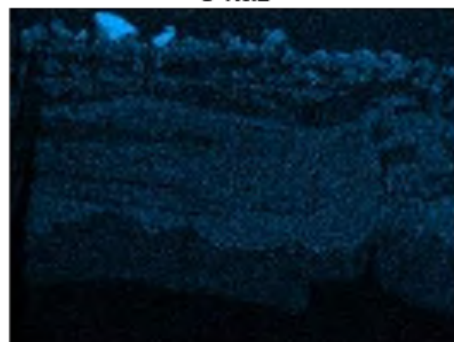
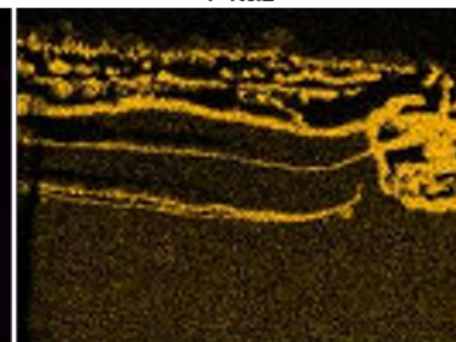
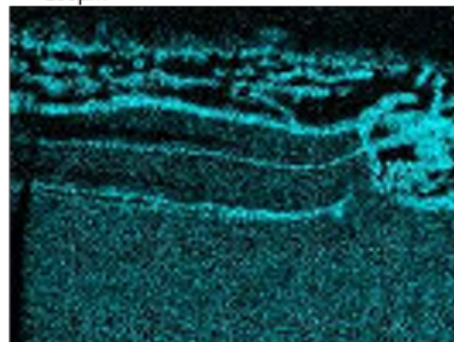
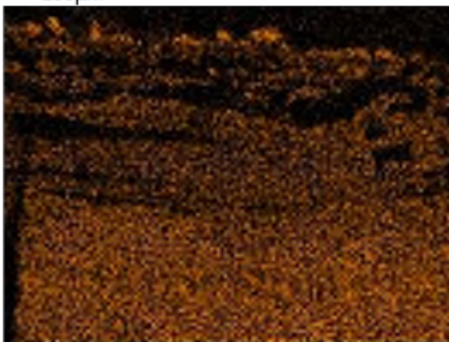
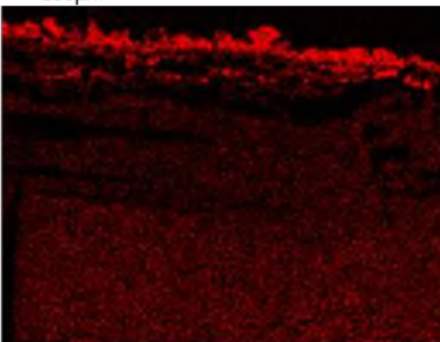
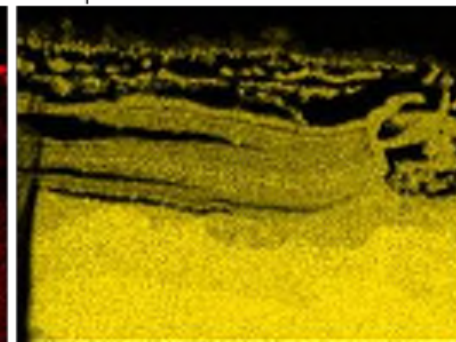
N:\JEN\11-1-Pb L5
16696

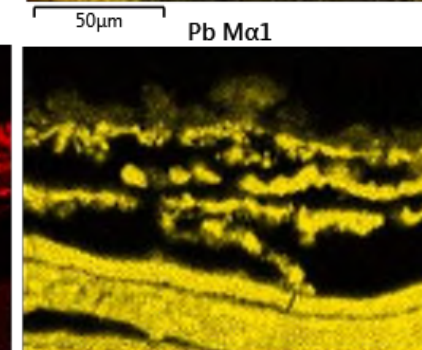
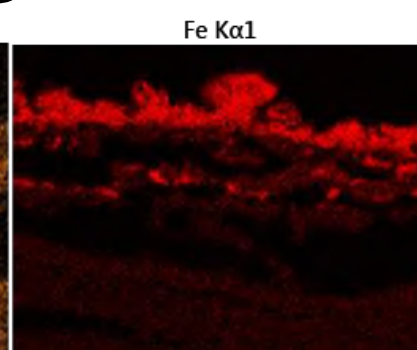
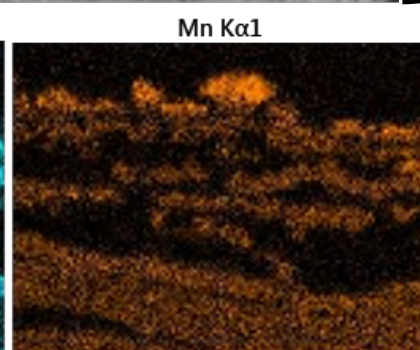
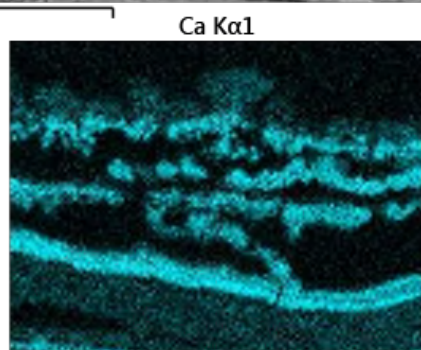
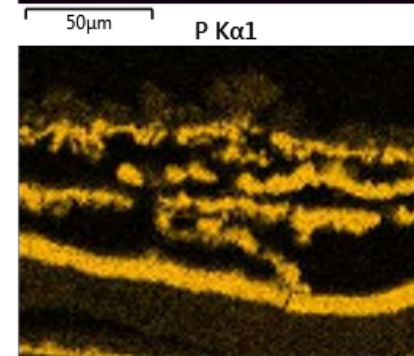
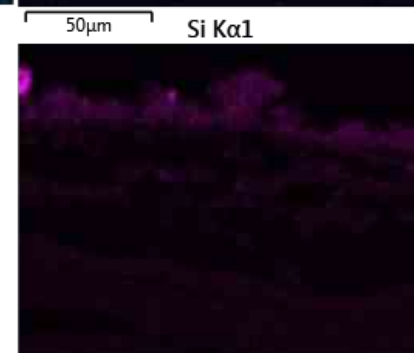
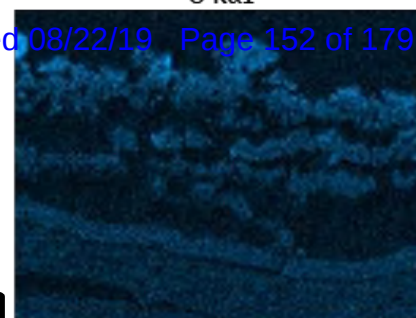
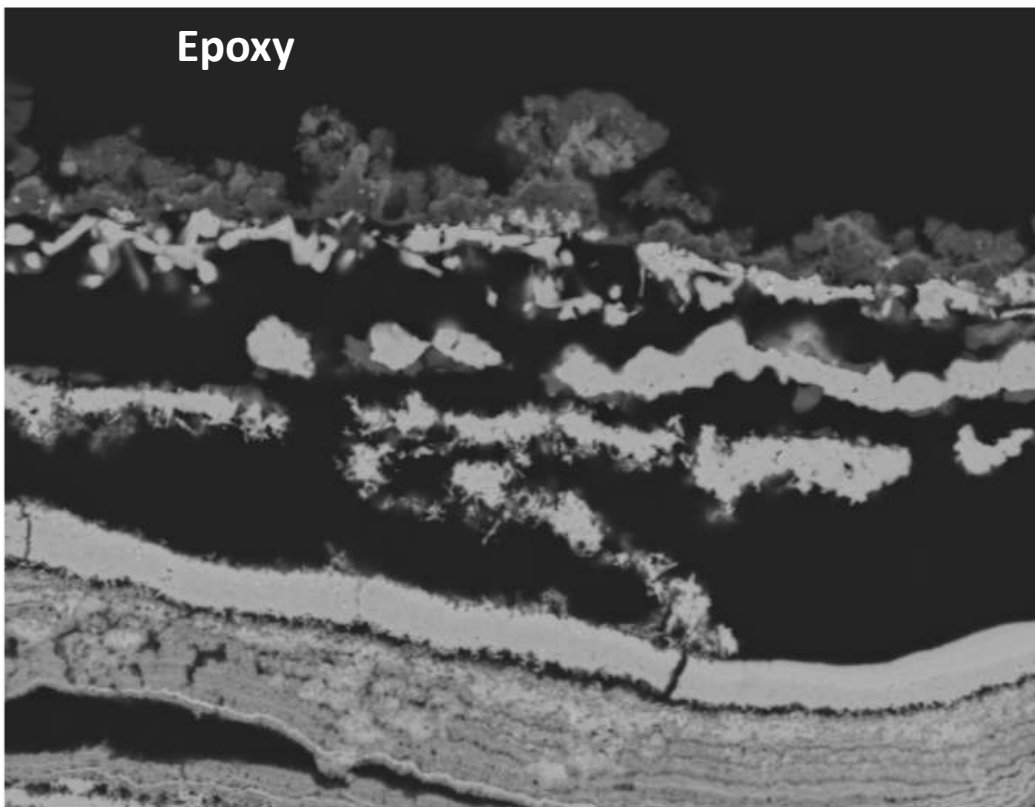
EDS Results Normalized to 100%	
Elements	Average (Wt %)
C*	1.3
O	17.6
Al	0.2
P	6.2
Ca	3.5
Fe	0.6
Pb	71.0

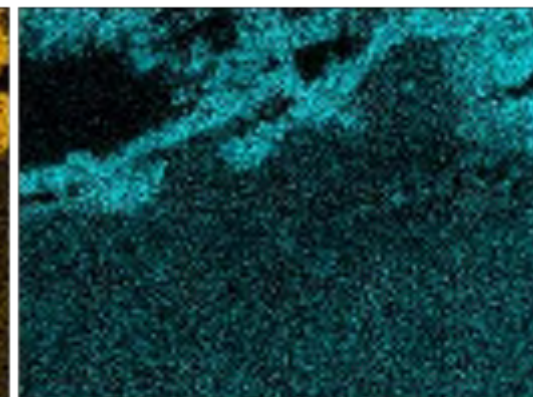
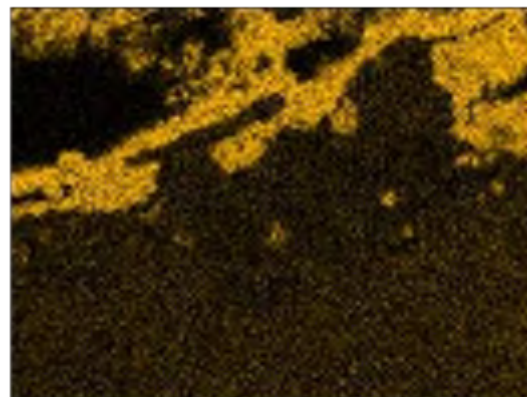
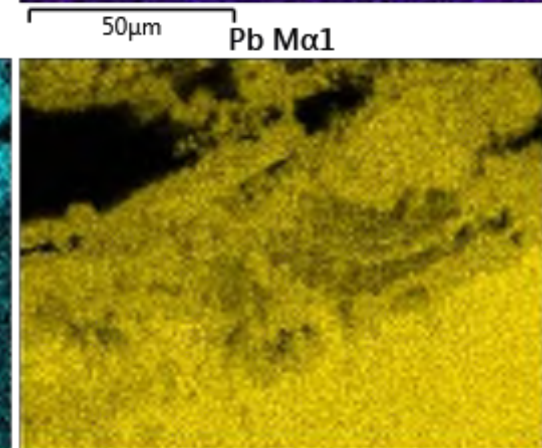
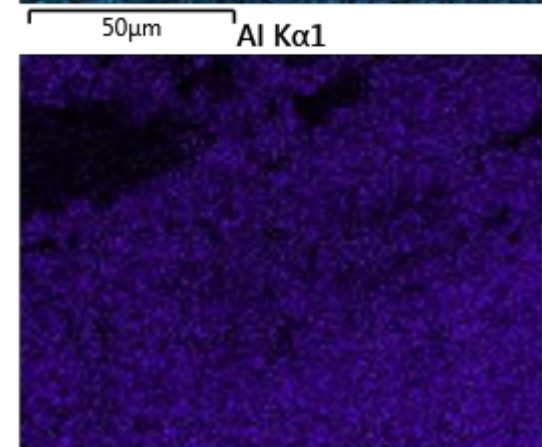
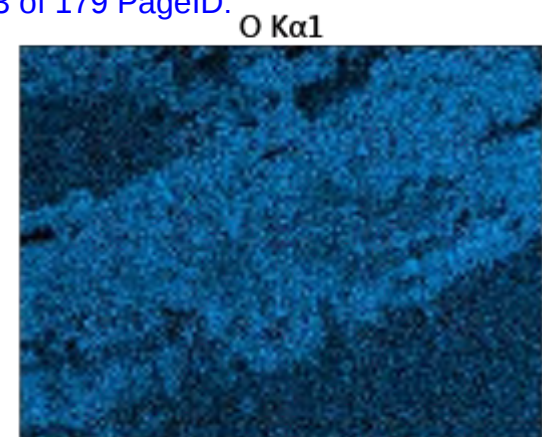
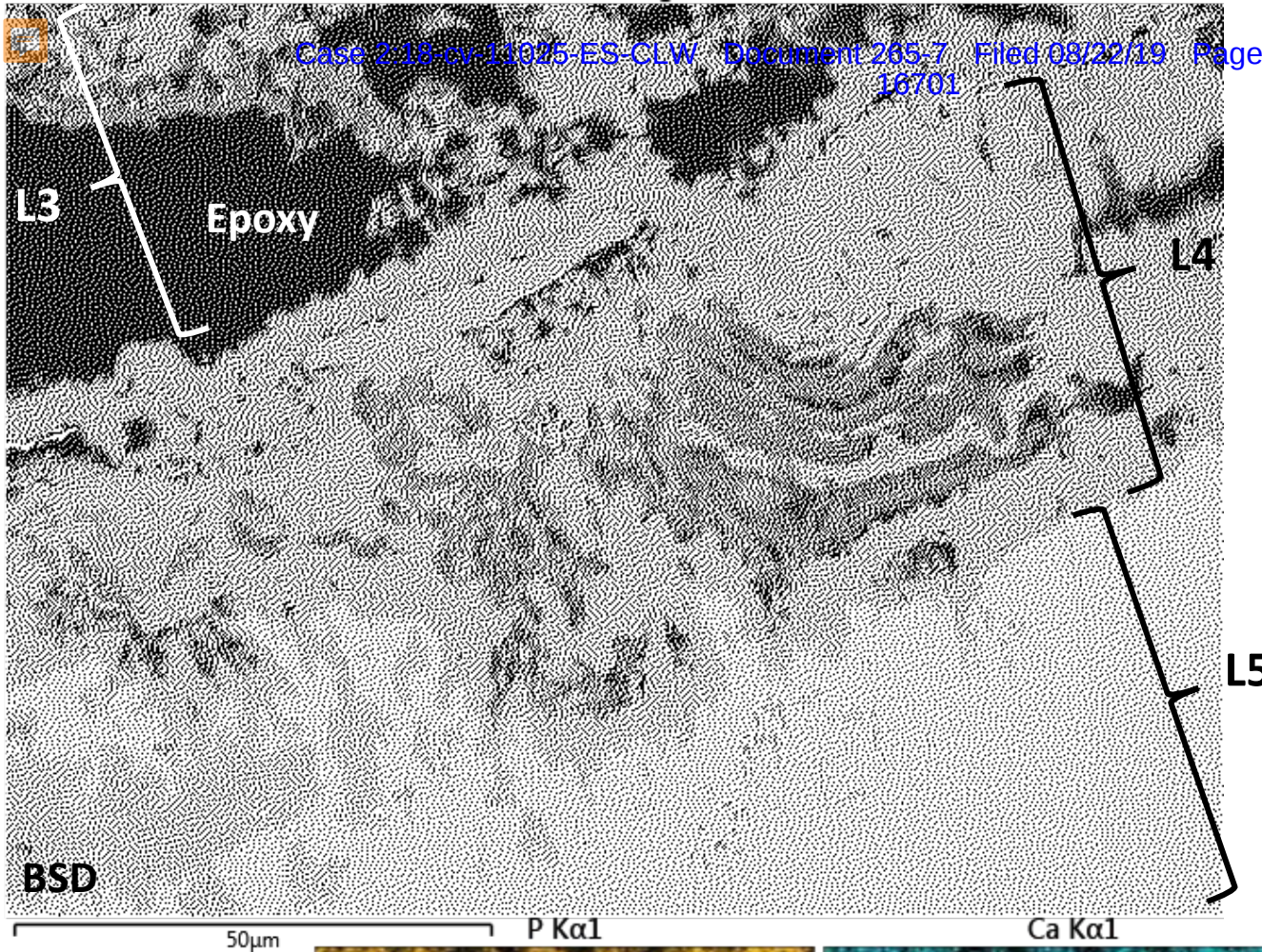
*C value was obtained by combustion





O K α 1Al K α 1Si K α 1P K α 1Ca K α 1Mn K α 1Fe K α 1Pb M α 1







Epoxy

Relict Plattnerite Texture/
Ca-hydroxypyromorphite

Plattnerite Texture

L1

L2

L3

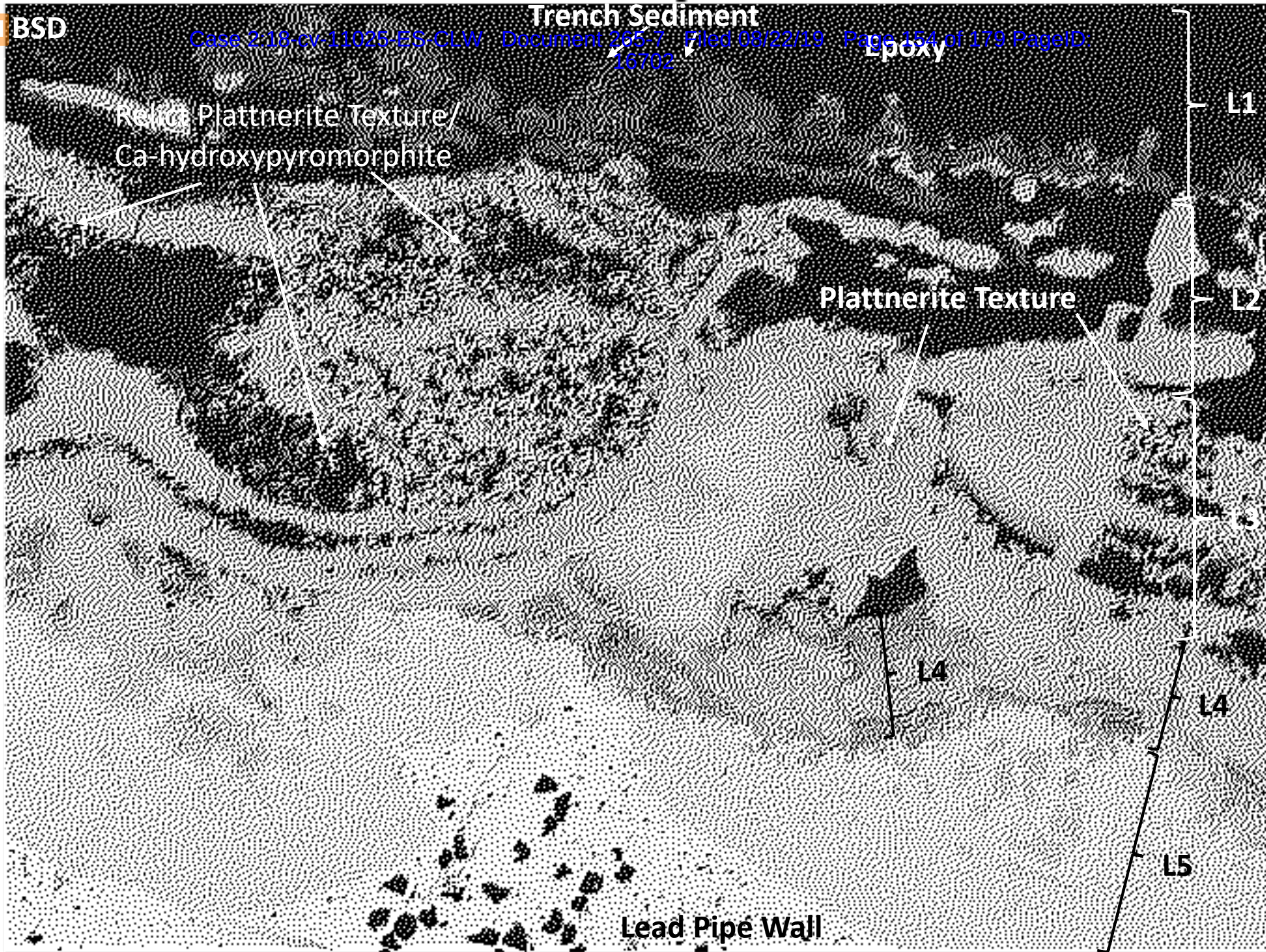
L4

L4

L5

Lead Pipe Wall

100µm



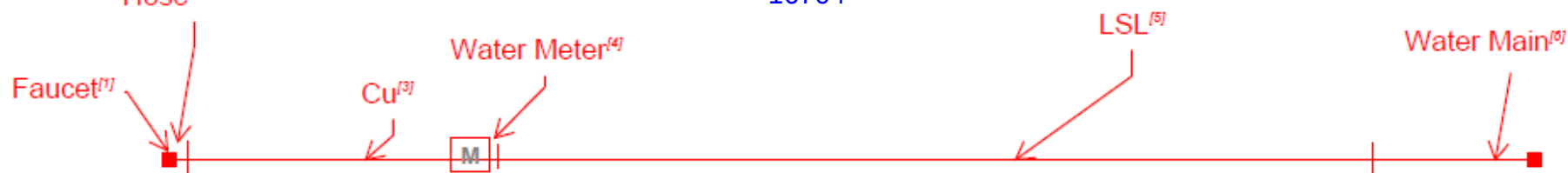


EDS Results, Normalized to 100%

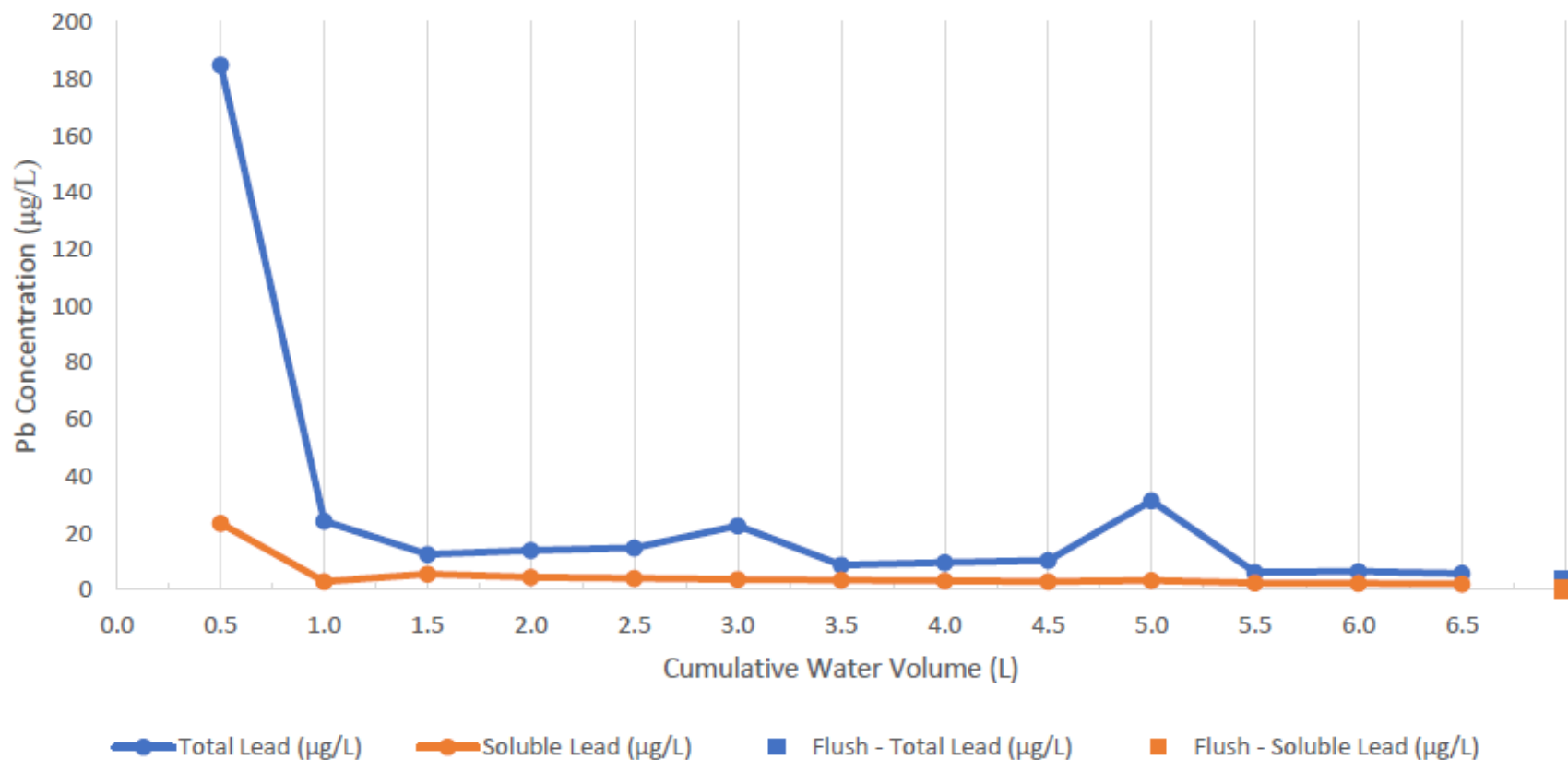
Elemental Concentrations as Average wt%

NJNEHIN1-Pb					
Elements	L1	L2	L3/L4	L4	L5
*C	1.01	1.28	1.93	2.98	1.37
O	32.1	22.5	16.4	15.4	12.9
Na	0.4	-	-	-	-
Mg	0.2	-	-	-	-
Al	2.6	0.9	0.2	0.2	0.2
Si	8.8	2.0	-	-	-
P	3.1	4.8	3.2	0.7	0.2
*S	0.13	0.12	0.15	0.27	0.13
K	0.4	-	-	-	-
Ca	1.5	2.5	1.7	0.4	0.2
Ti	0.2	-	-	-	-
Mn	1.2	0.4	0.1	-	-
Fe	7.5	3.1	0.3	0.1	0.1
Pb	40.8	62.5	75.9	80.1	85.0

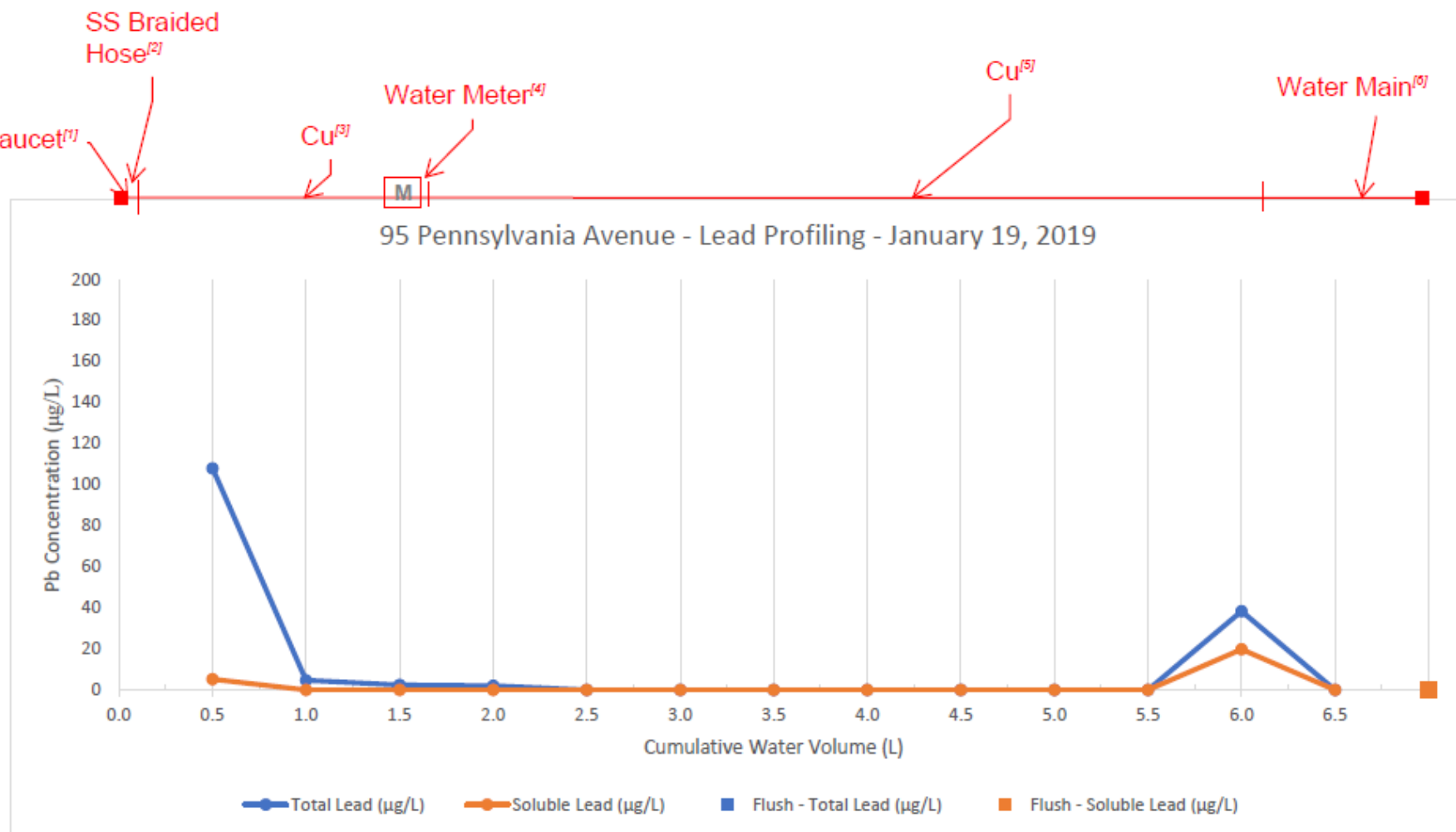
*C and S by combustion



95 Pennsylvania Avenue - Lead Profiling - December 14, 2018



Before LSL replacement



After LSL replacement



Newark, NJ
Lead Service Line
Address: 95 Pennsylvania Ave.
Installed: 1887
Removed: December 20, 2018

Tubercles
indicated by
white arrows





95 Pennsylvania Avenue - December 14, 2018

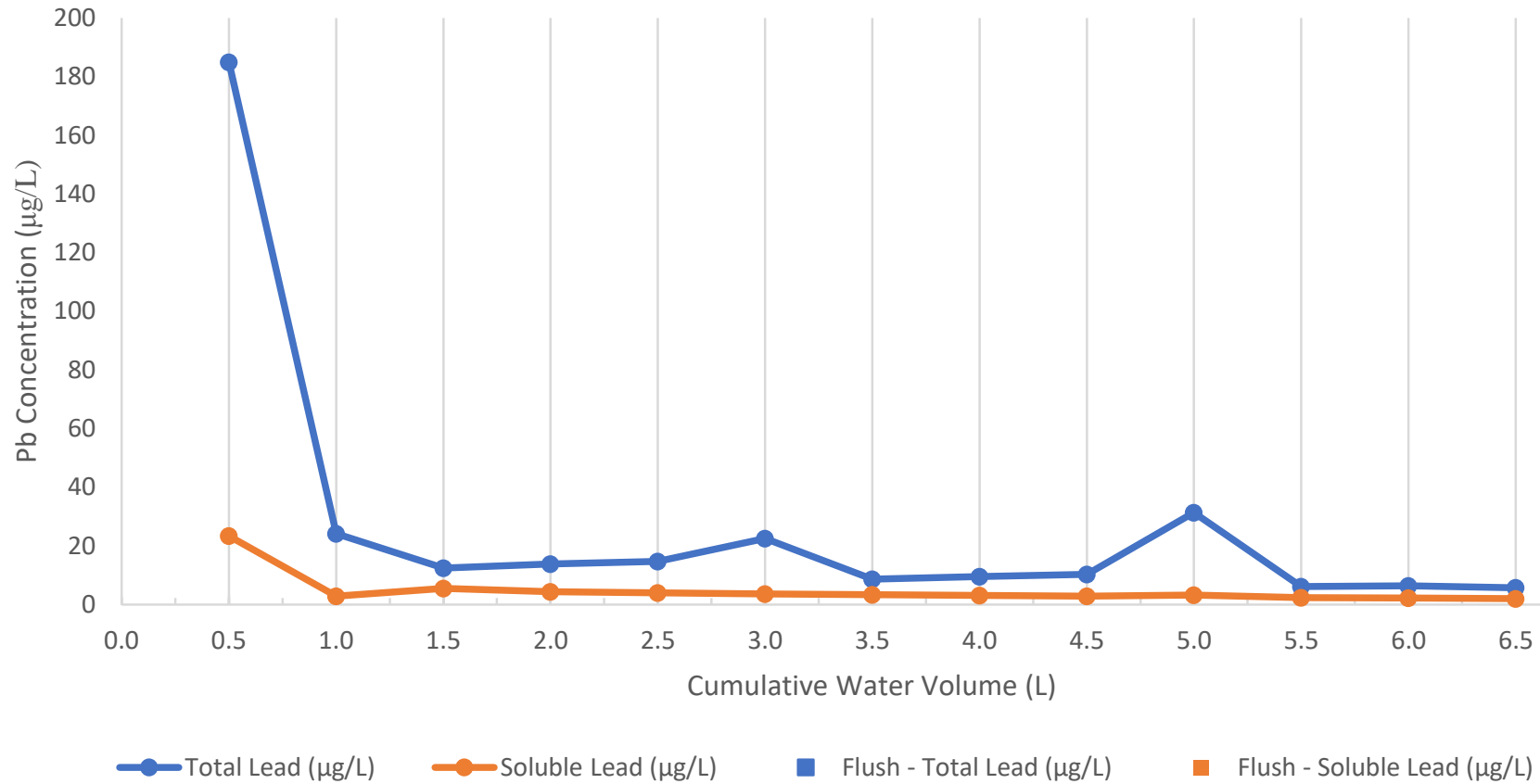


Table 1-1F
City of Newark Sequential Monitoring
Analytical Results
95 Pennsylvania

Site F - 12/14/18

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹ (degrees C)	Free Cl ₂ ¹ (mg/L)	Total Pb (µg/L)	Dissolved Pb (µg/L)	Total Cu (mg/L)	Alk. (mg/L as CaCO ₃)	Cond. umhos/cm	Orthophosphate (mg/L as P)	Silica (mg/L as SiO ₂)	
F1	500	500	After Stagnation	N/A	N/A	N/A	185	23.4	0.0596	33.0	251	0.396		Faucet (28% SS Flex) and Copper Piping with Lead Solder (72%)
F2	500	1000	After Stagnation				24.2	2.86	0.0737			0.48	3.75	Copper Piping with Lead Solder (100%)
F3	500	1500	After Stagnation				12.5	5.52	<.0500			0.497		Copper Piping with Lead Solder (100%)
F4	500	2000	After Stagnation				13.8	4.41	0.0521			0.5		Copper Piping (14%), Lead Piping (86%)
F5	500	2500	After Stagnation				14.7	4	<.05			0.516		Lead Piping (100%)
F6	500	3000	After Stagnation	N/A	N/A	N/A	22.6	3.63	0.0576	31	252	0.503	3.64	Lead Piping (100%)
F7	500	3500	After Stagnation				8.68	3.37	0.0551			0.517		Lead Piping (100%)
F8	500	4000	After Stagnation				9.53	3.07	<.05			0.52		Lead Piping (100%)
F9	500	4500	After Stagnation				10.3	2.94	0.239			0.524		Lead Piping (100%)
F10	500	5000	After Stagnation				31.4	3.31	0.0596			0.524		Lead Piping (100%)
F11	500	5500	After Stagnation				6.14	2.38	<.05			0.555		Lead Piping (100%)
F12	500	6000	After Stagnation				6.43	2.21	<.05			0.545		Lead Piping (100%)
F13	500	6500	After Stagnation				5.74	2.04	<.05			0.543		Lead Piping (27%), Water Main (73%)
F14 FLUSH	500	7000	Flushed after the sequential sampling	N/A	N/A	N/A	2.96	<2.0	<.05	23.0	248	0.546	3.24	Water Main (100%)

NOTES
1. pH, temperature, and free and total chlorine will be field measured.
2. **HOMEOWNER SHOULD FLUSH THE LINE FOR 10 MINUTES BEFORE BEGINNING STAGNATION PERIOD (i.e. night before sampling).**

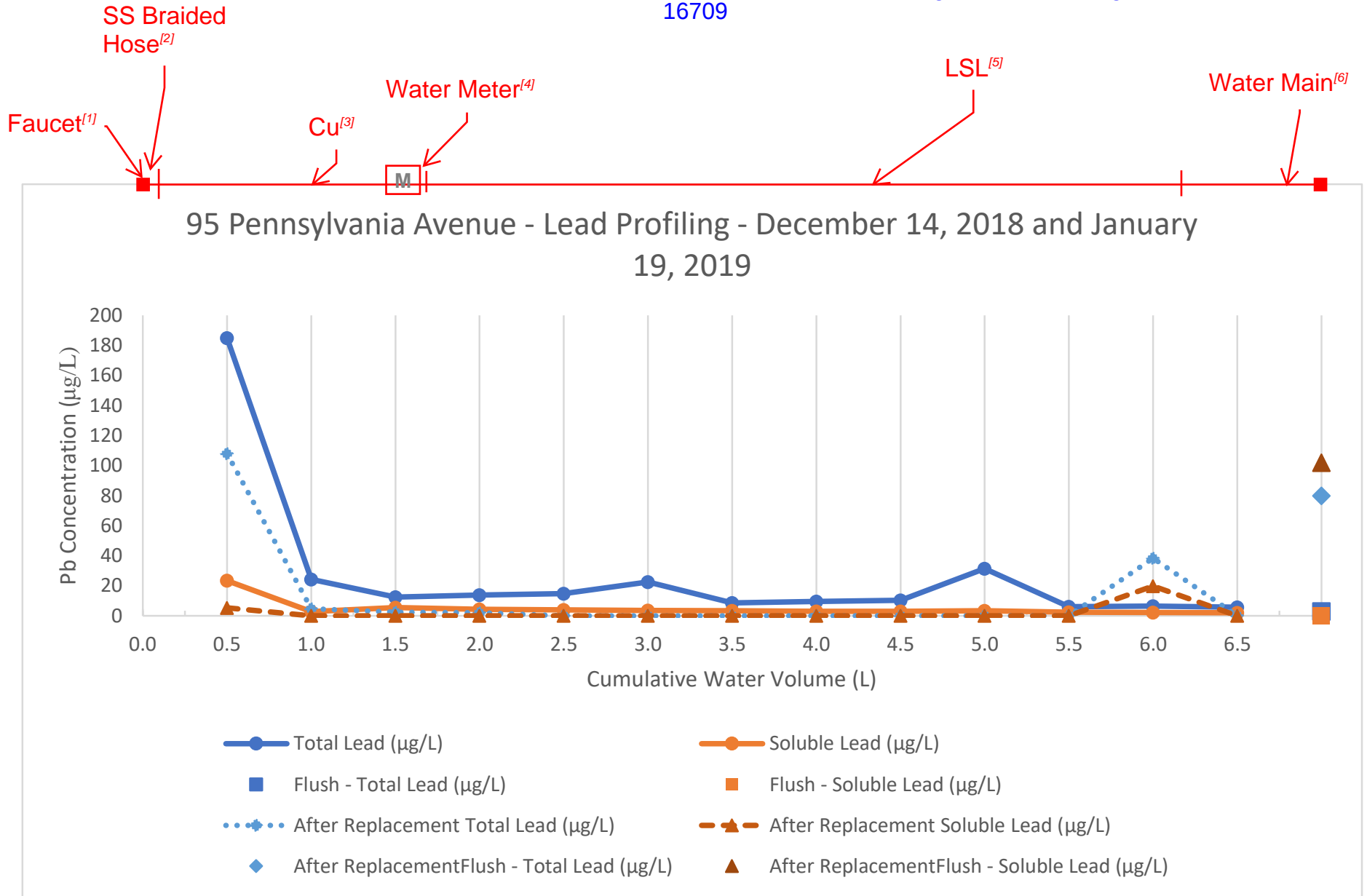
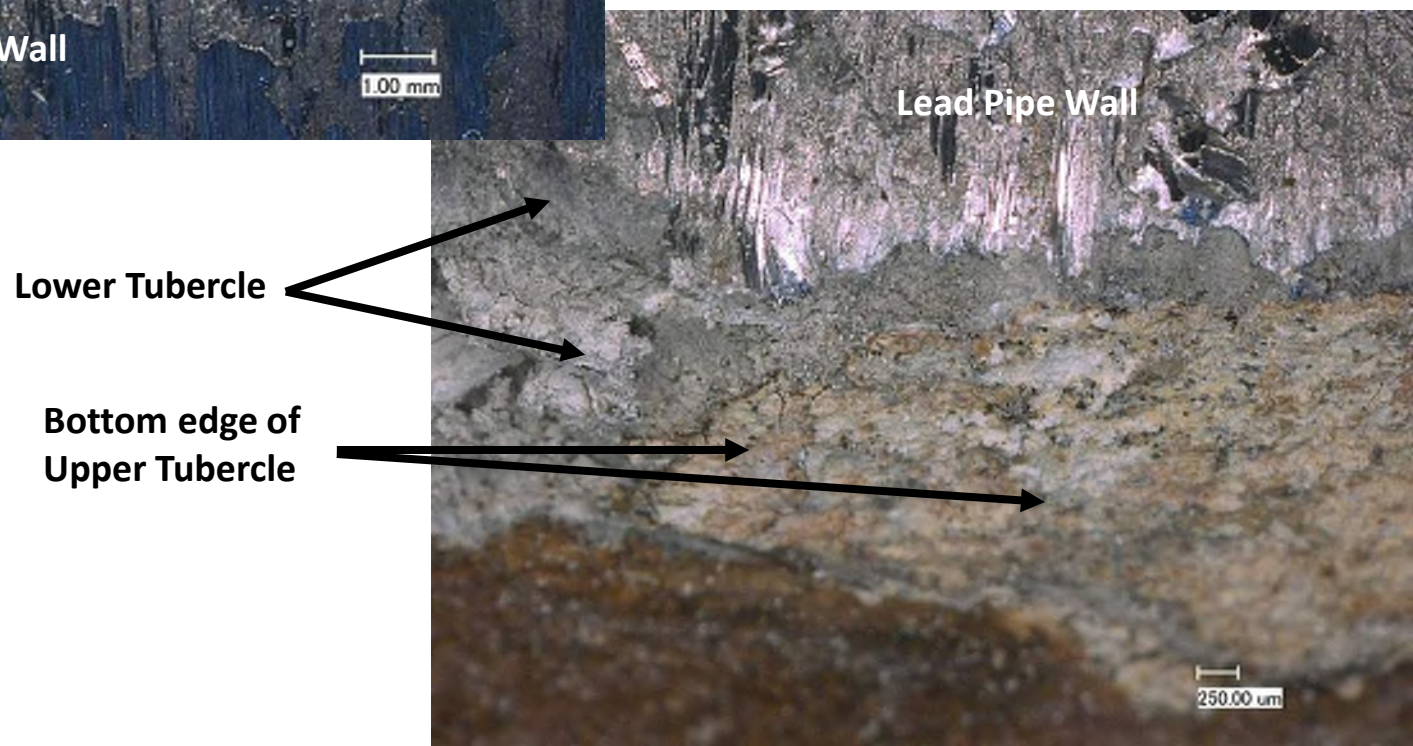
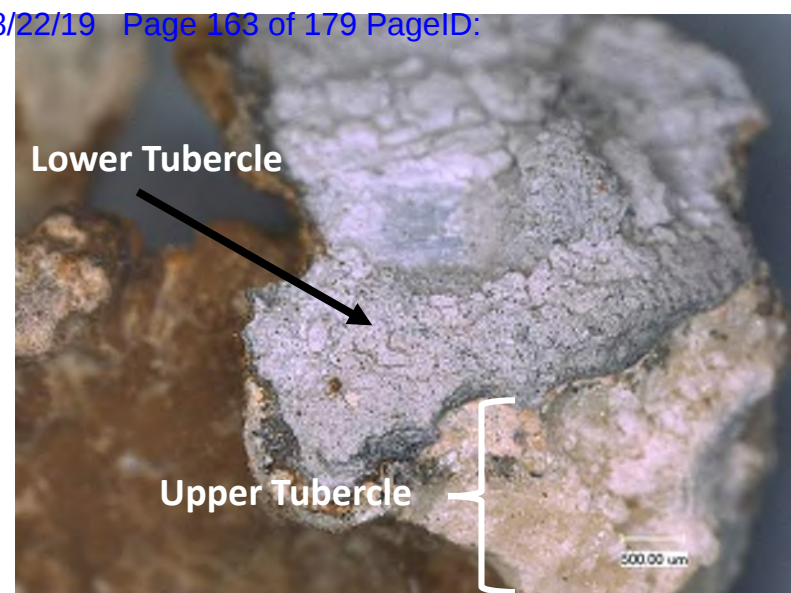
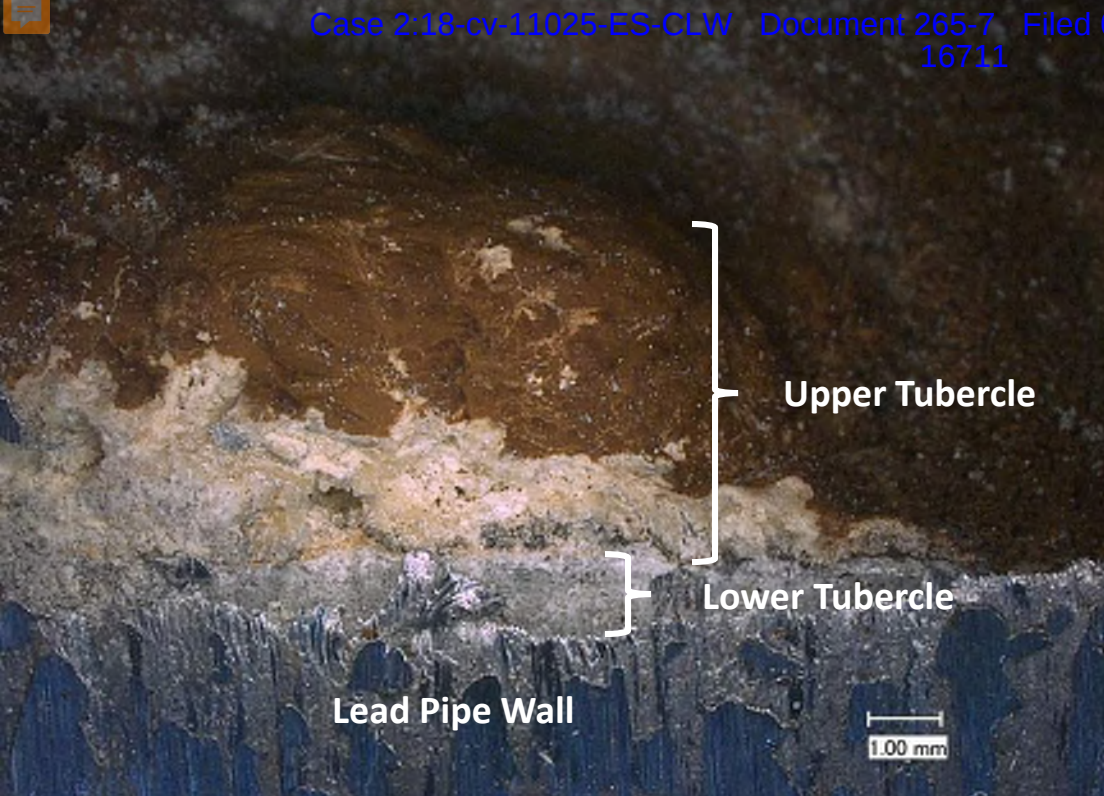


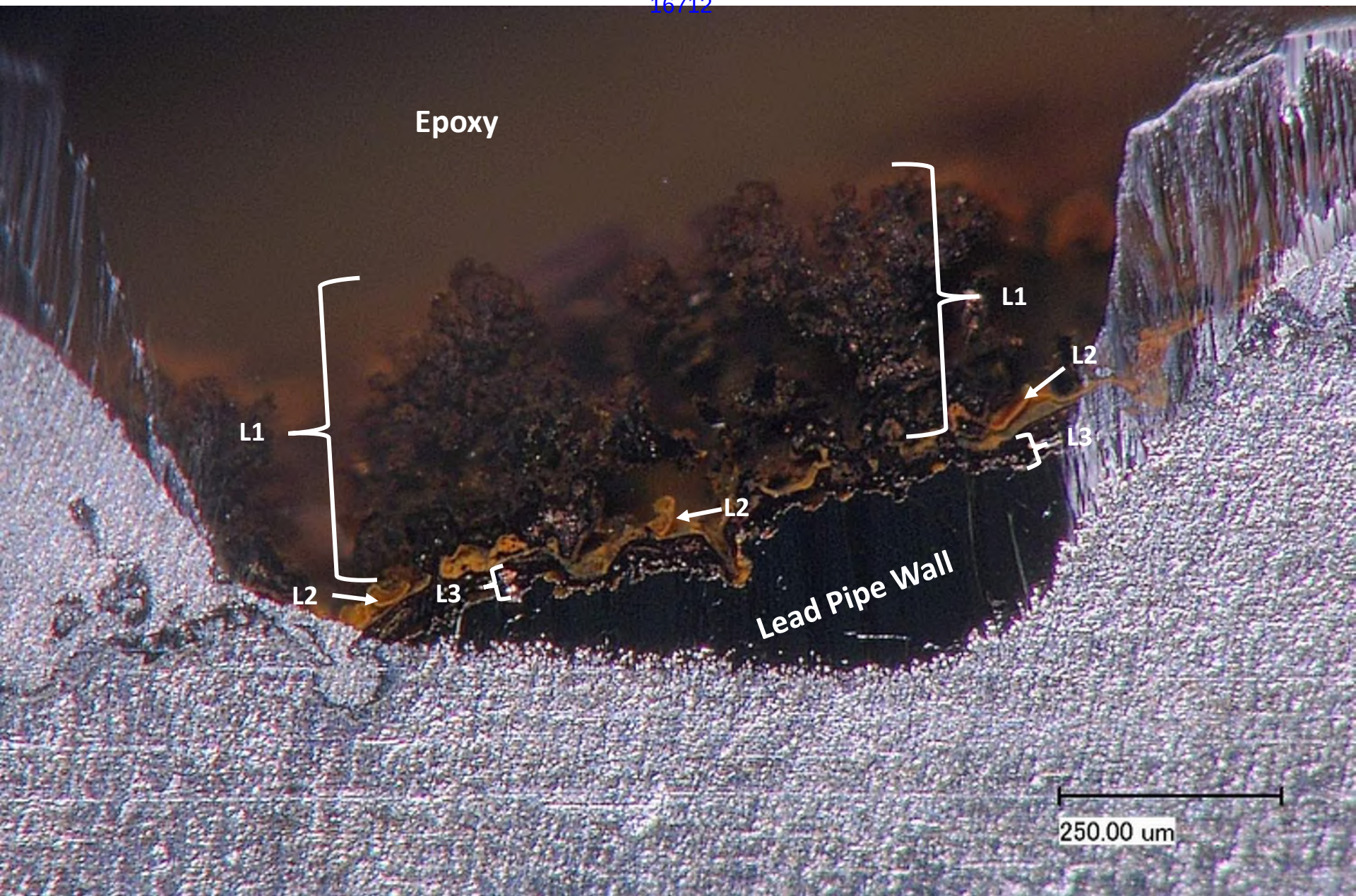
Table 1-1L
City of Newark Sequential Monitoring
Analytical Results
95 Pennsylvania
After Lead Service Line Replacement

Site L -1/19/19

Sample	Volume (mL)	Cumulative Volume (mL)	Collection	Water Quality Parameters										Location/ Description
				pH ¹	Temp ¹ (degrees C)	Free Cl ₂ ¹ (mg/L)	Total Pb (µg/L)	Dissolved Pb (µg/L)	Total Cu (mg/L)	Alk. (mg/L as CaCO ₃)	Cond. umhos/cm	Orthophosphate (mg/L as P)	Silica (mg/L as SiO ₂)	
L1	500	500	After Stagnation	6.97	15.0	0.04	108.00	5.24	<.05	34.0	215			Faucet (28% SS Flex) and Copper Piping with Lead Solder (72%)
L2	500	1000	After Stagnation				4.75	<2	0.072			0.739		Copper Piping with Lead Solder (100%)
L3	500	1500	After Stagnation				2.40	<2	0.118					Copper Piping with Lead Solder (100%)
L4	500	2000	After Stagnation				2.06	<2	0.147					Copper Piping (14%), Lead Piping (86%)
L5	500	2500	After Stagnation				<2	<2	0.153					Lead Piping (100%)
L6	500	3000	After Stagnation	6.99	12.8	0.06	<2	<2	0.170	31	244			Lead Piping (100%)
L7	500	3500	After Stagnation				<2	<2	0.206			0.686		Lead Piping (100%)
L8	500	4000	After Stagnation				<2	<2	0.194					Lead Piping (100%)
L9	500	4500	After Stagnation				<2	<2	0.198					Lead Piping (100%)
L10	500	5000	After Stagnation				<2	<2	0.162					Lead Piping (100%)
L11	500	5500	After Stagnation				<2	<2	0.151					Lead Piping (100%)
L12	500	6000	After Stagnation				38.30	19.8	0.350					Lead Piping (100%)
L13	500	6500	After Stagnation				<2	<2	0.151					Lead Piping (27%), Water Main (73%)
L14 FLUSH	500	7000	Flushed after the sequential sampling	7.07	8.1	0.56	<2	<2	0.014	25.0	243	1.54		Water Main (100%)

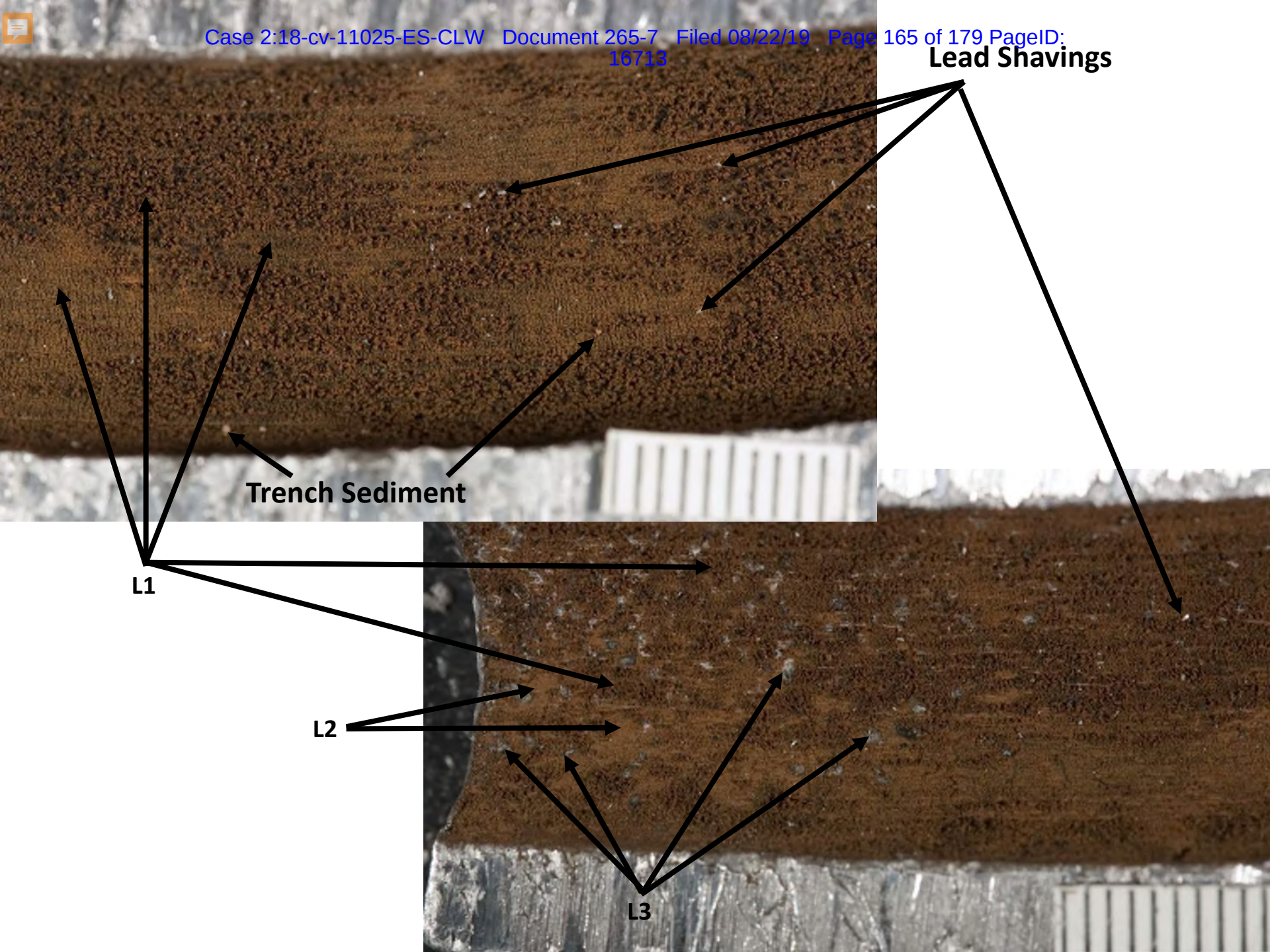
NOTES
1. pH, temperature, and free and total chlorine will be field measured.
2. **HOMEOWNER SHOULD FLUSH THE LINE FOR 10 MINUTES BEFORE BEGINNING STAGNATION PERIOD (i.e. night before sampling).**

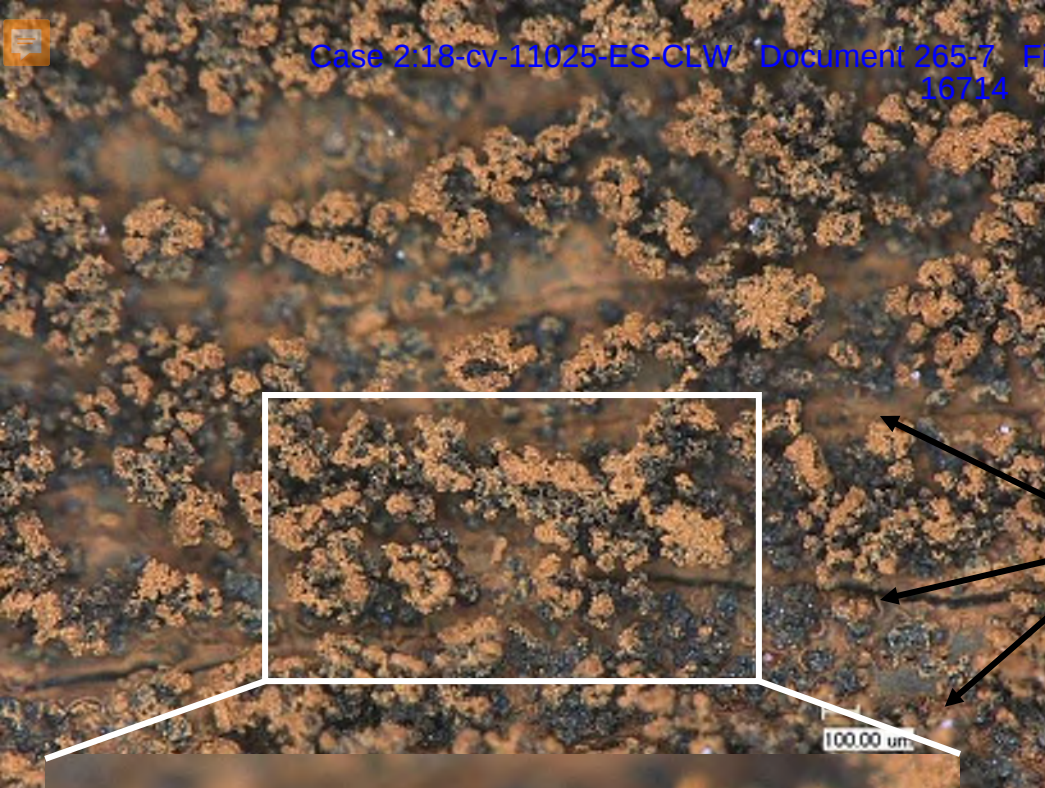




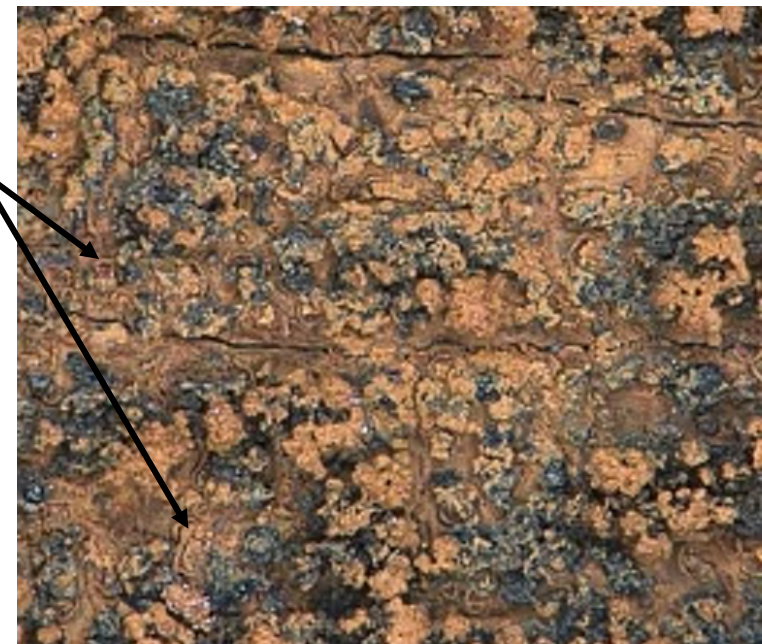


Lead Shavings





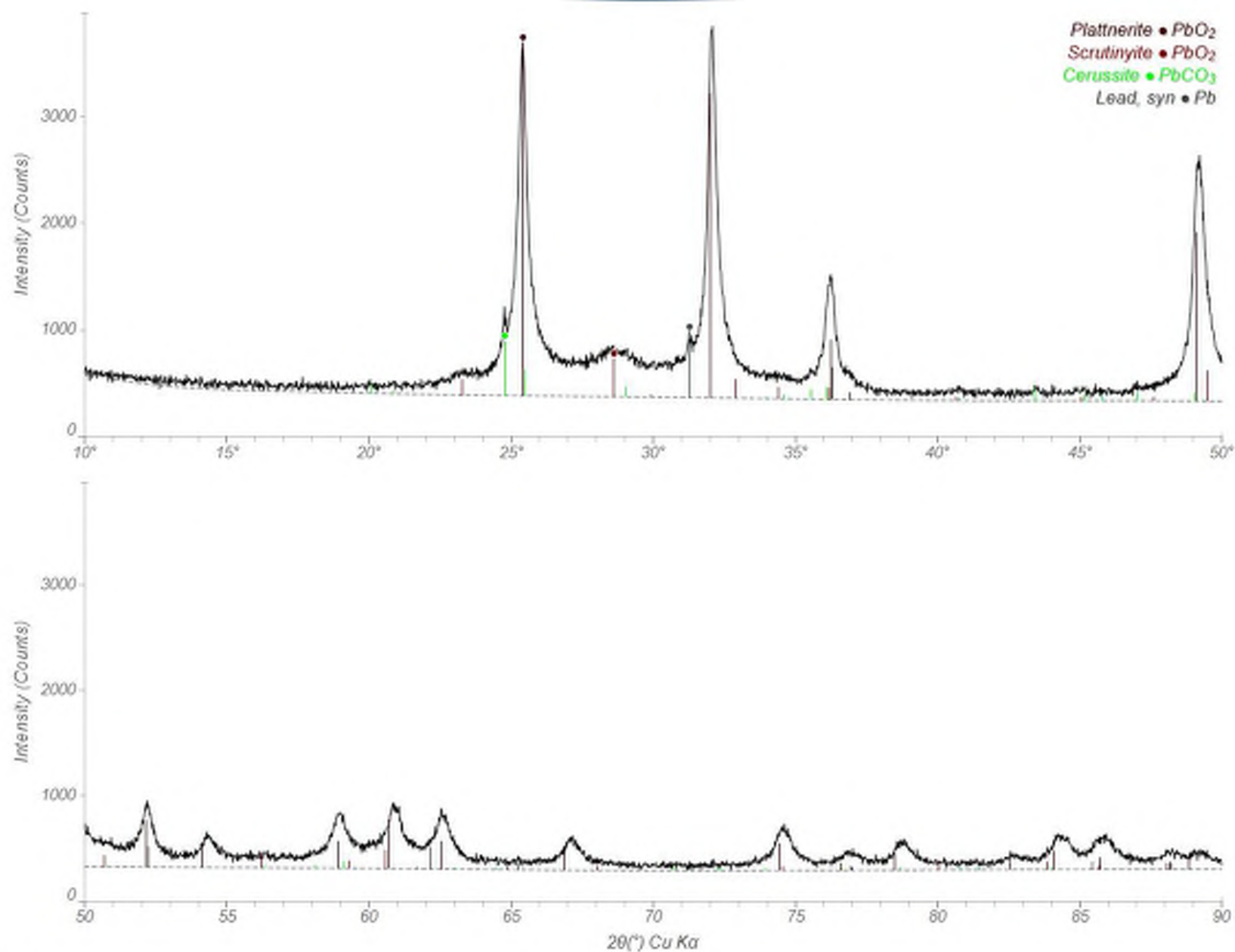
L2

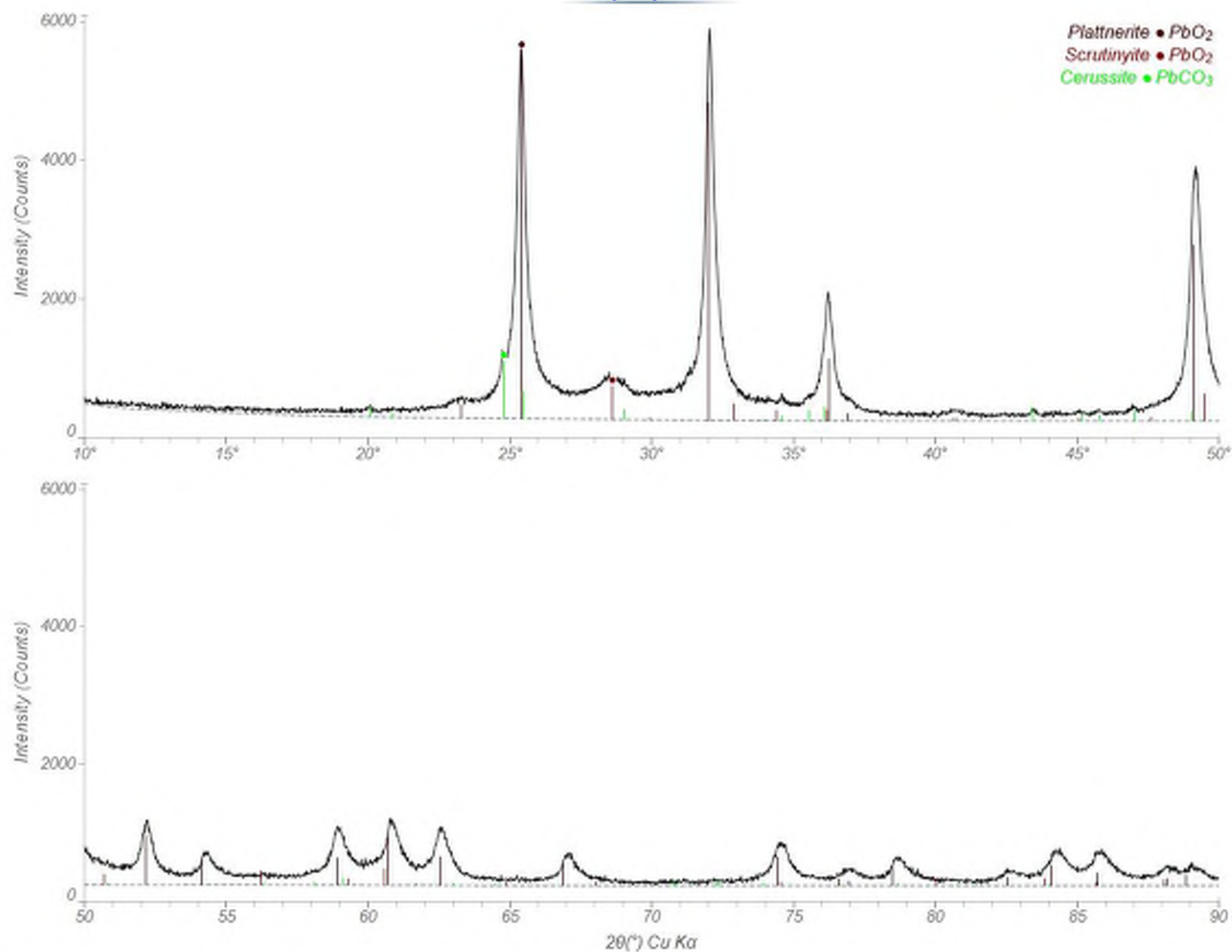


L1

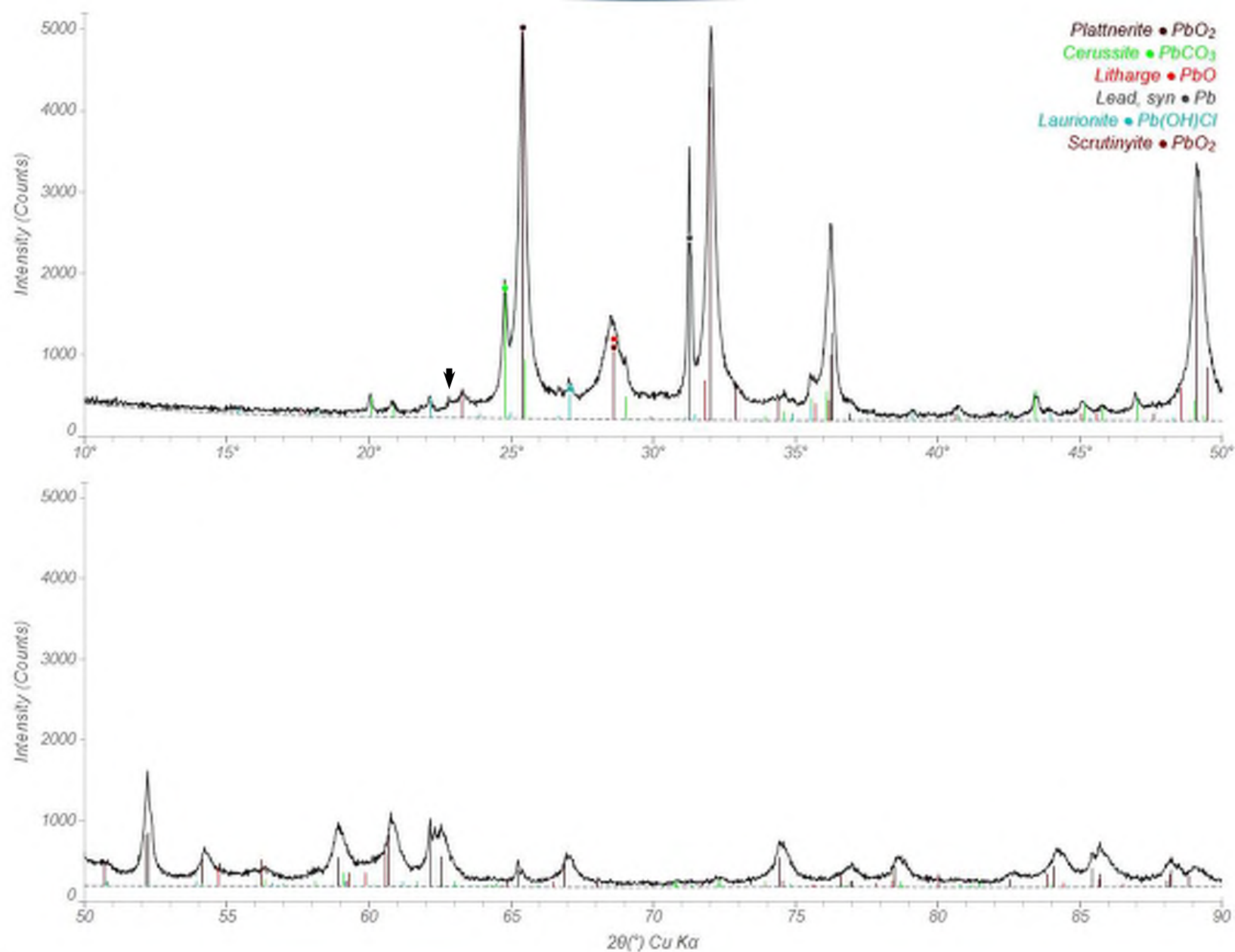


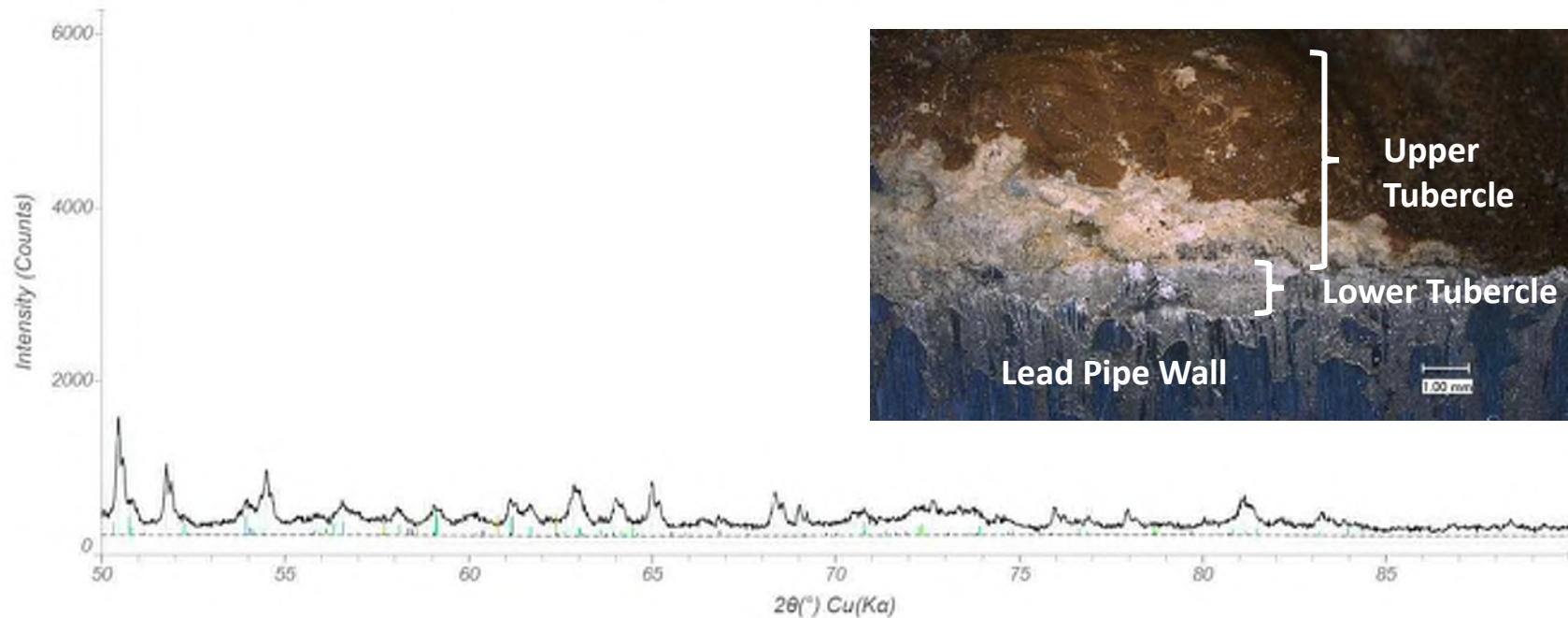
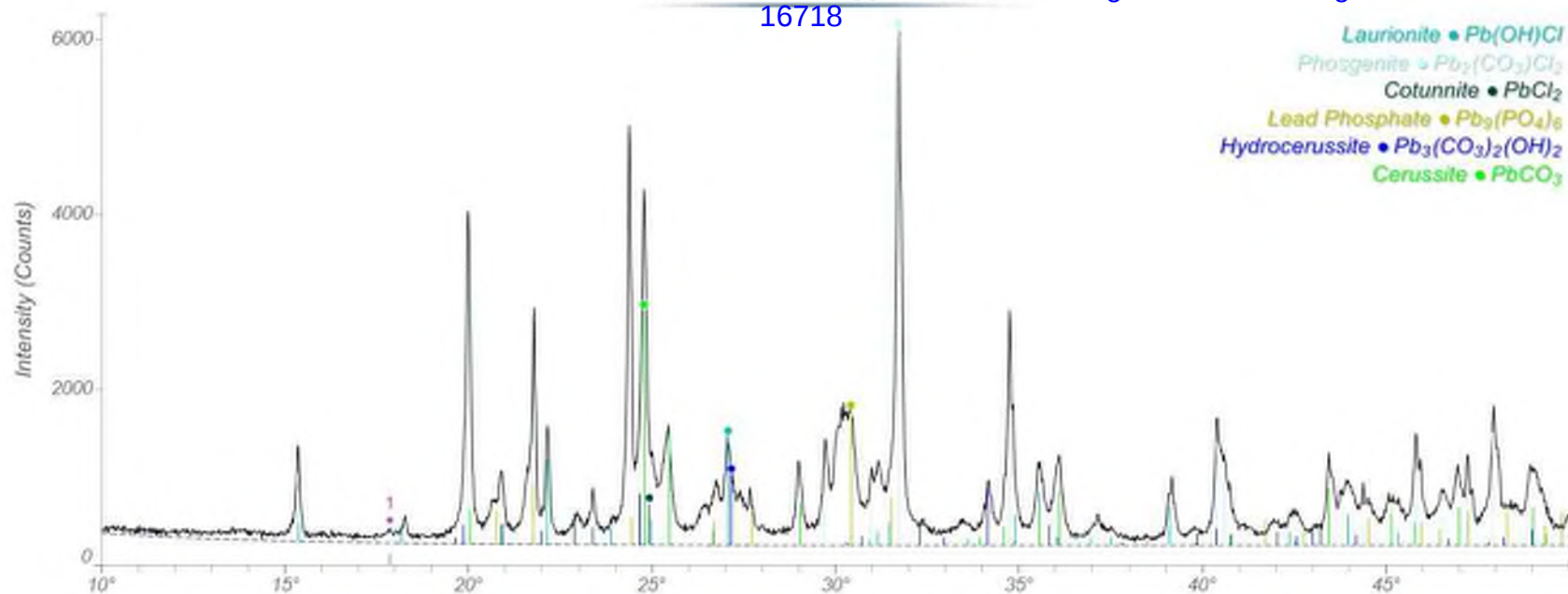
NJNEP01-Pb L1

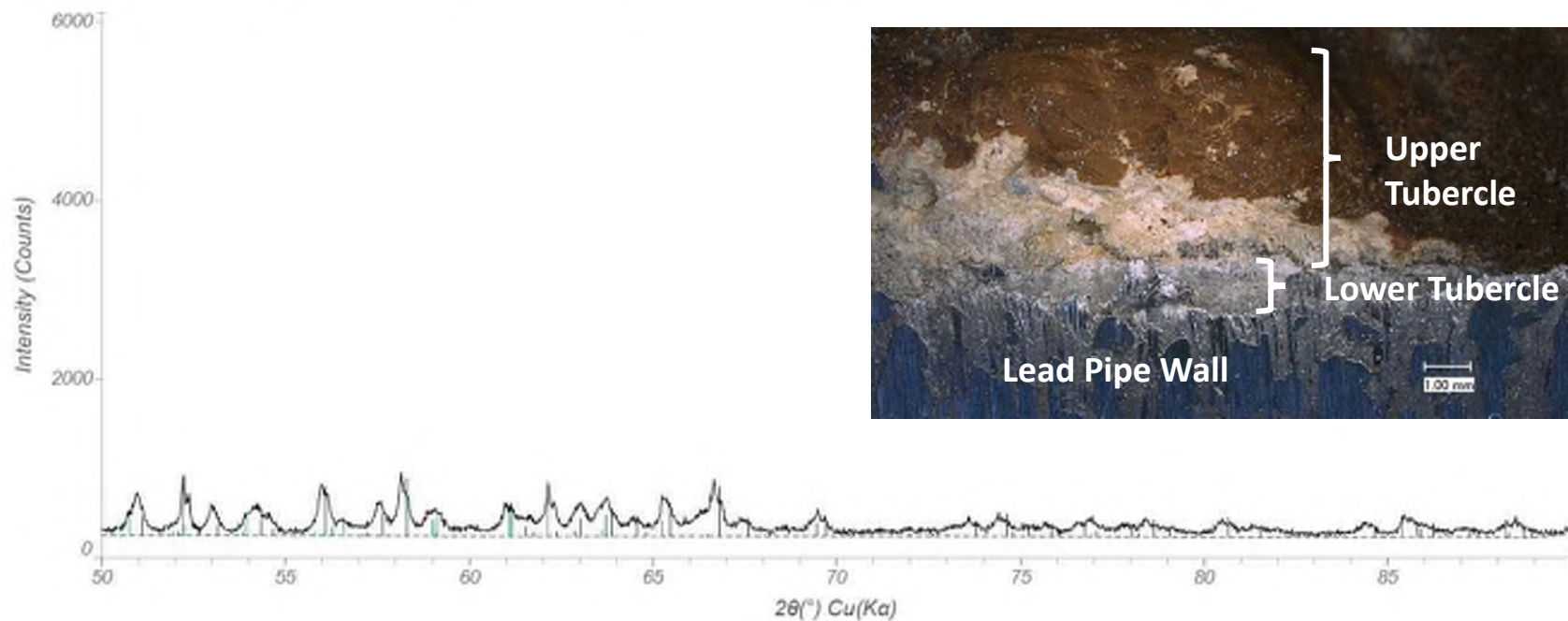
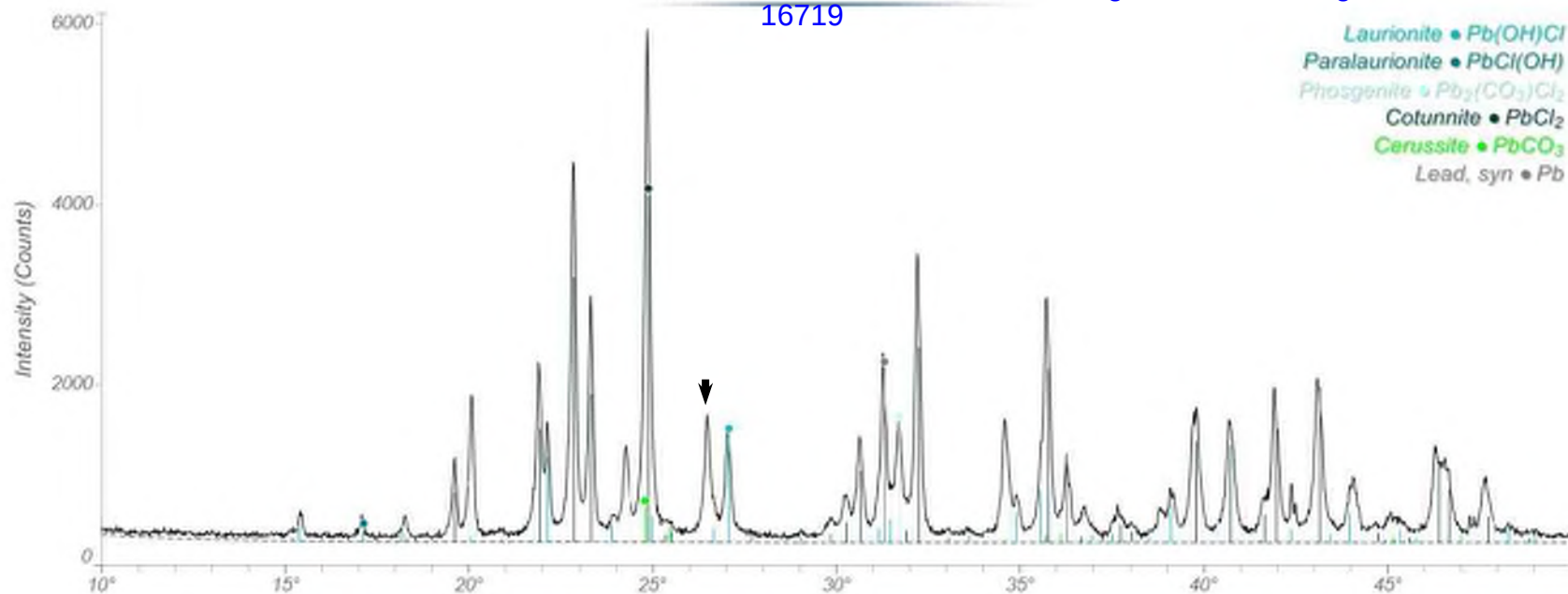


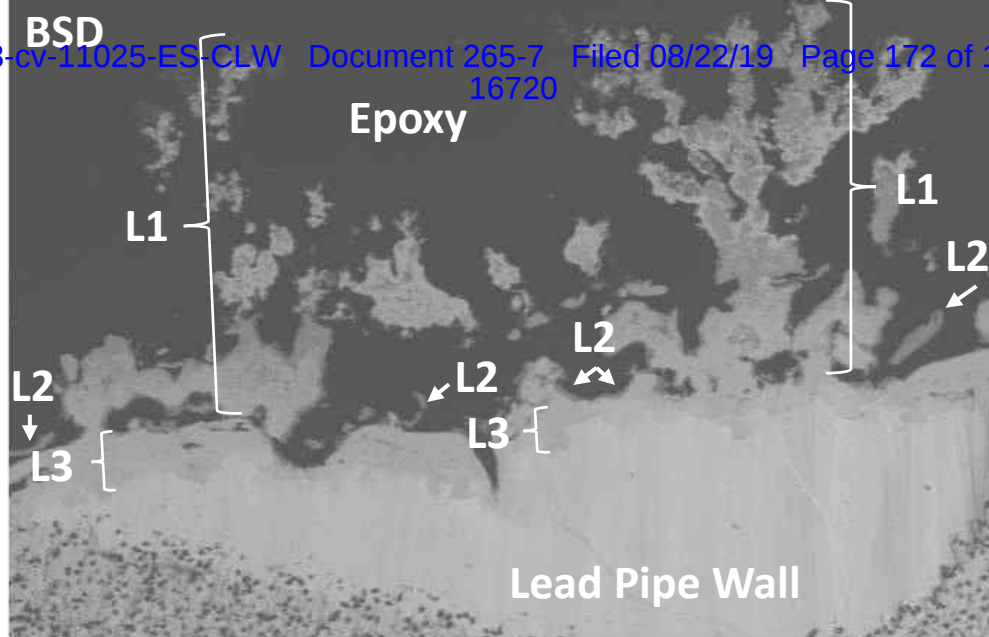
NJNEDEN1-Pb L2
16716

NJNEDEN1-Pb L3

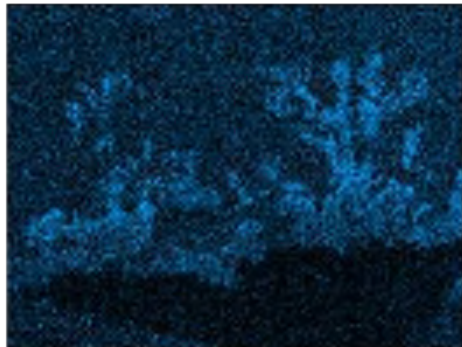




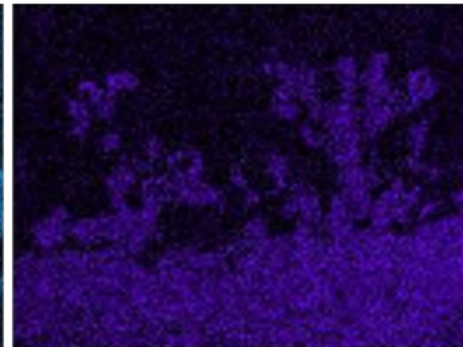




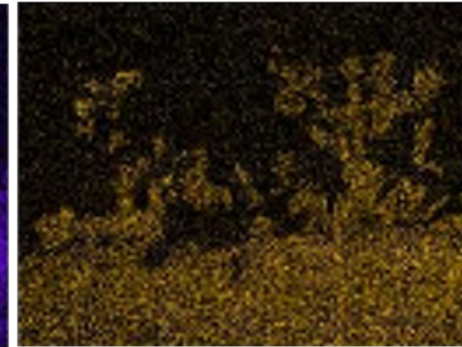
O Kα1



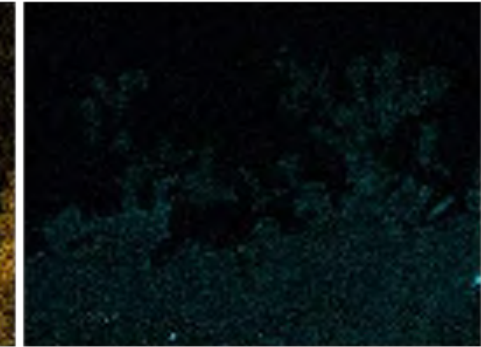
Al Kα1



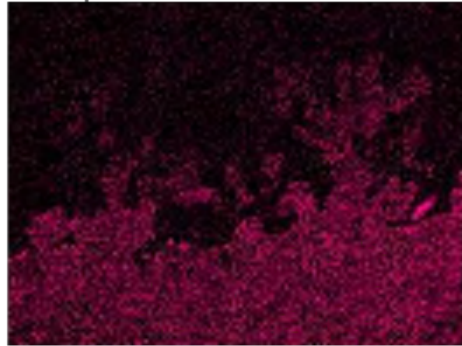
P Kα1



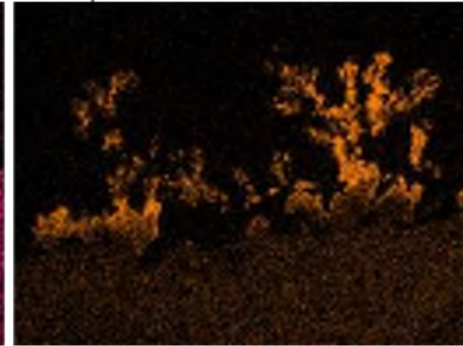
Ca Kα1



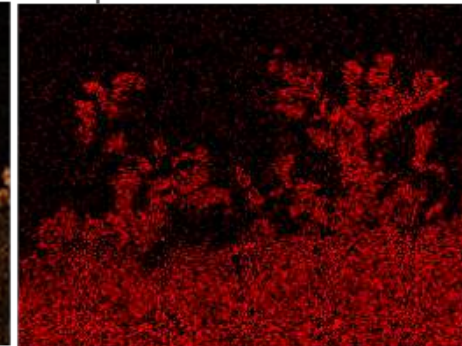
Sn Lα1



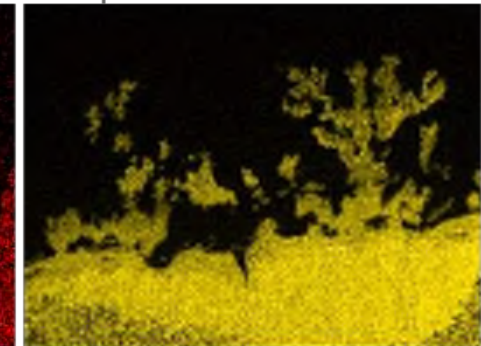
Mn Kα1

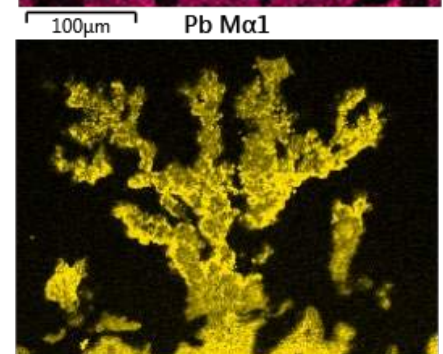
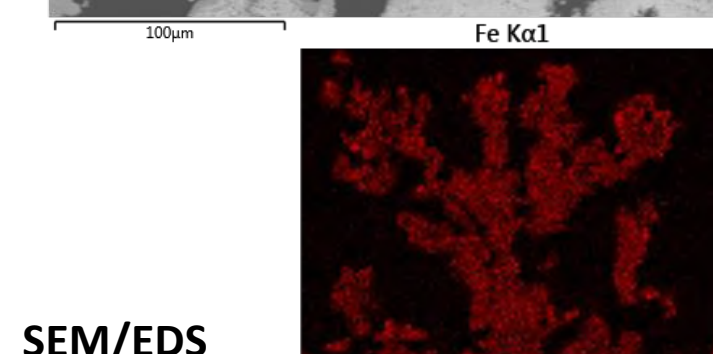
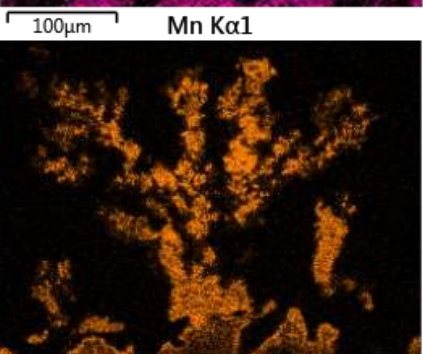
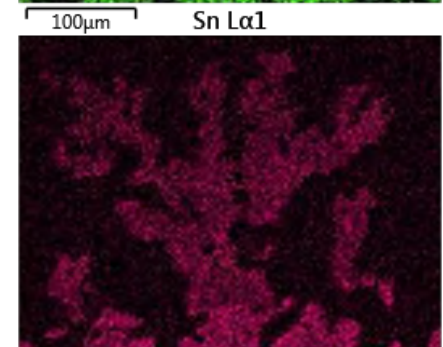
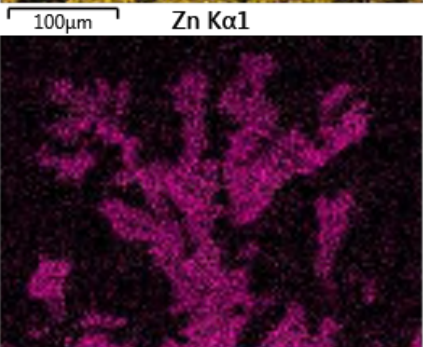
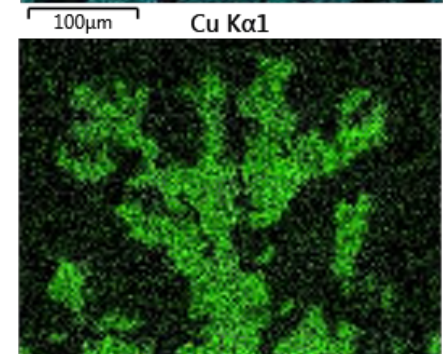
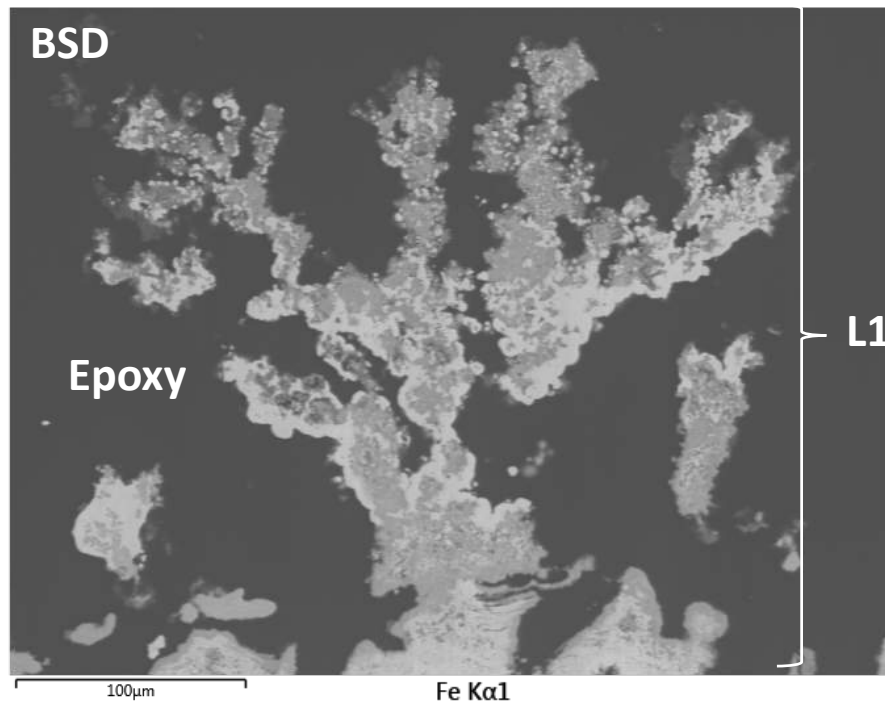
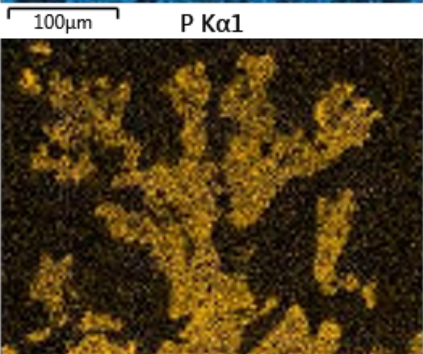
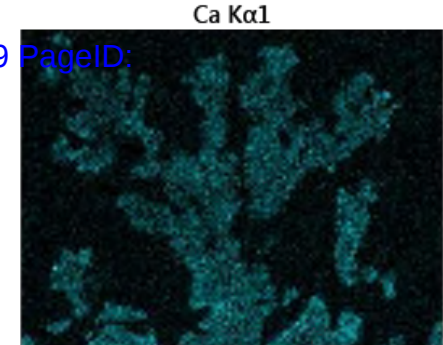
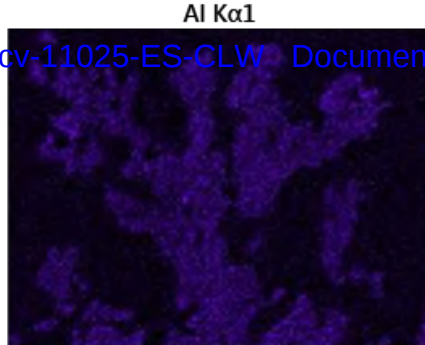
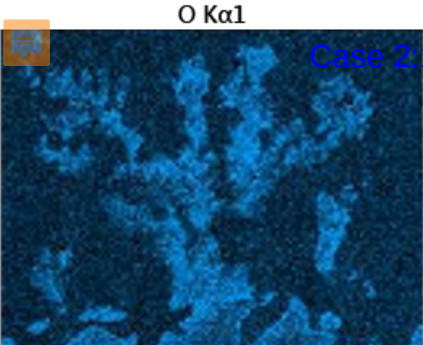


Fe Kα1



Pb Mα1





SEM/EDS



O K α 1

Mg K α 1_2

Al K α 1

Si K α 1

Ca K α 1

Case 2:18-cv-11025-ES-CLW Document 265-7 Filed 08/22/19 Page 174 of 179 PageID:
16722

25 μ m

25 μ m

25 μ m

25 μ m

25 μ m

BSD

P K α 1

Cu K α 1

L1

Epoxy

25 μ m

25 μ m

Zn K α 1

Sn L α 1

V K α 1

Fe K α 1

Pb M α 1

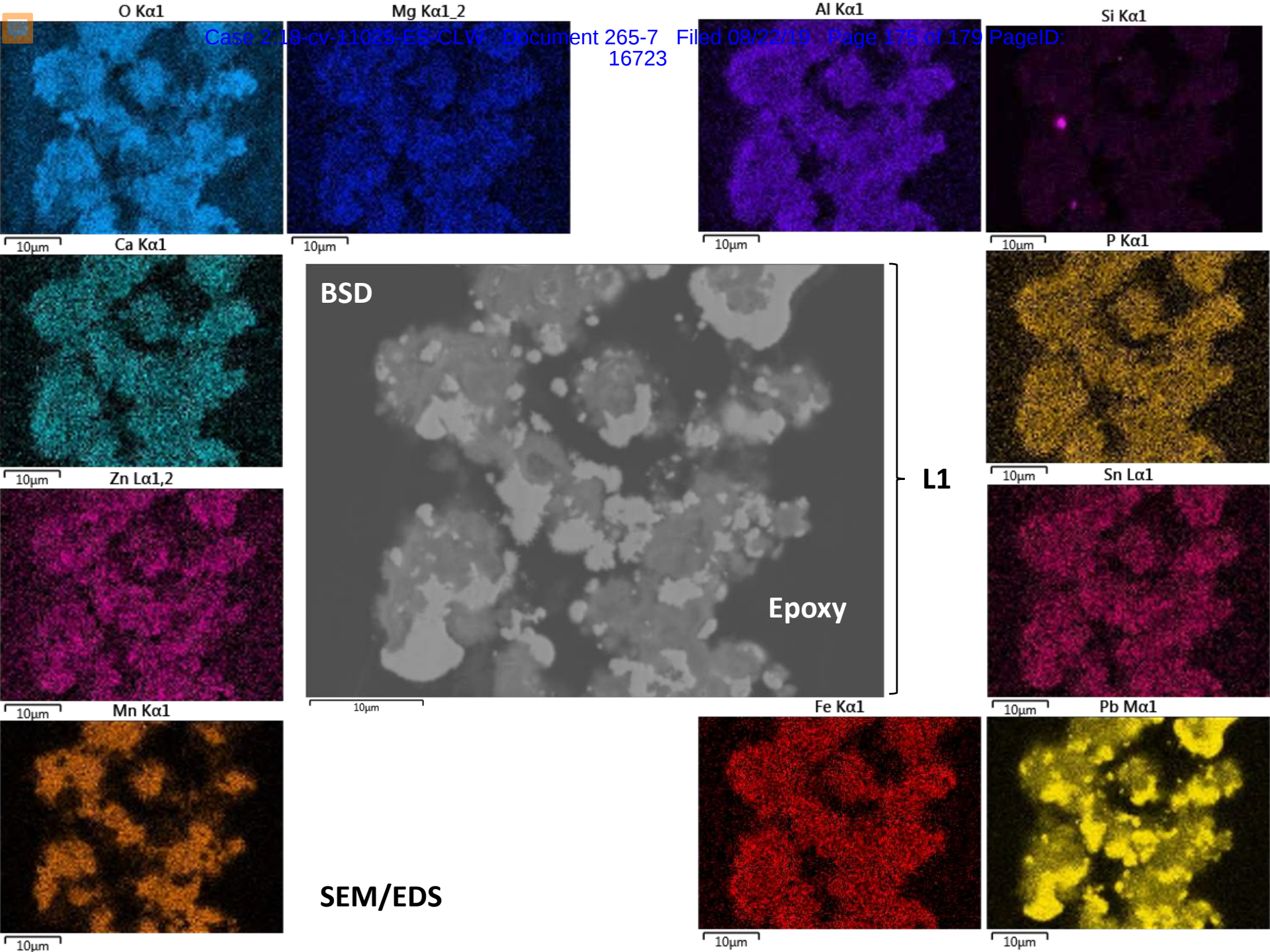
25 μ m
Mn K α 1

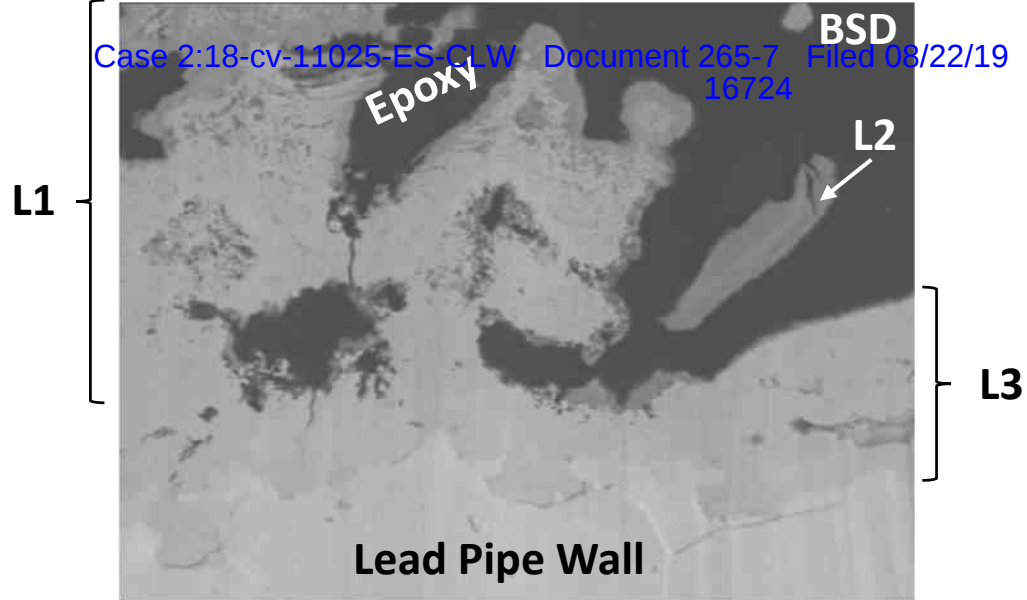
25 μ m

25 μ m

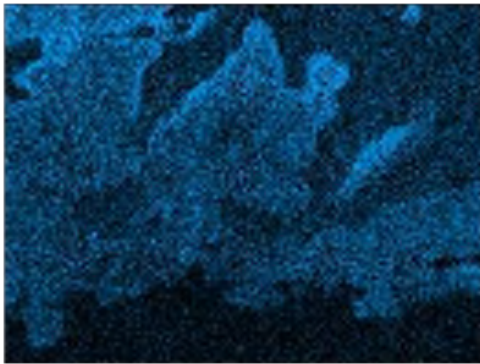
25 μ m

SEM/EDS



O K α 1

50µm

Al K α 1Ca K α 1P K α 1Sn L α 1

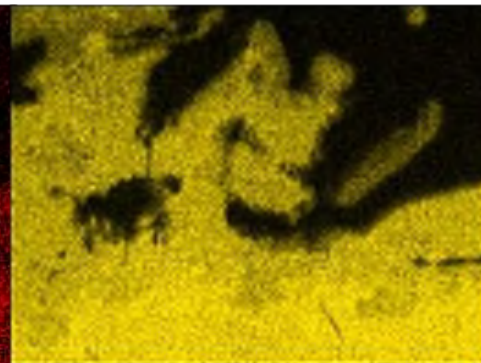
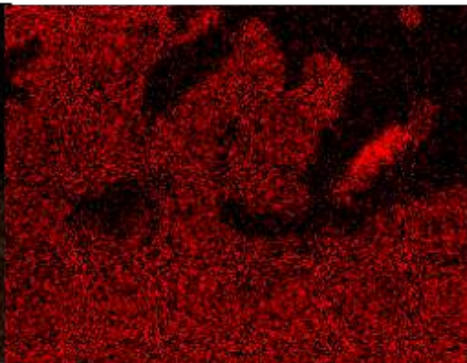
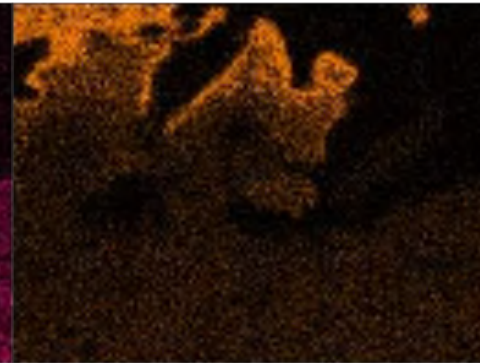
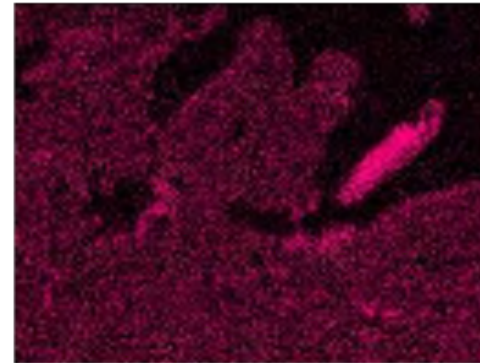
50µm

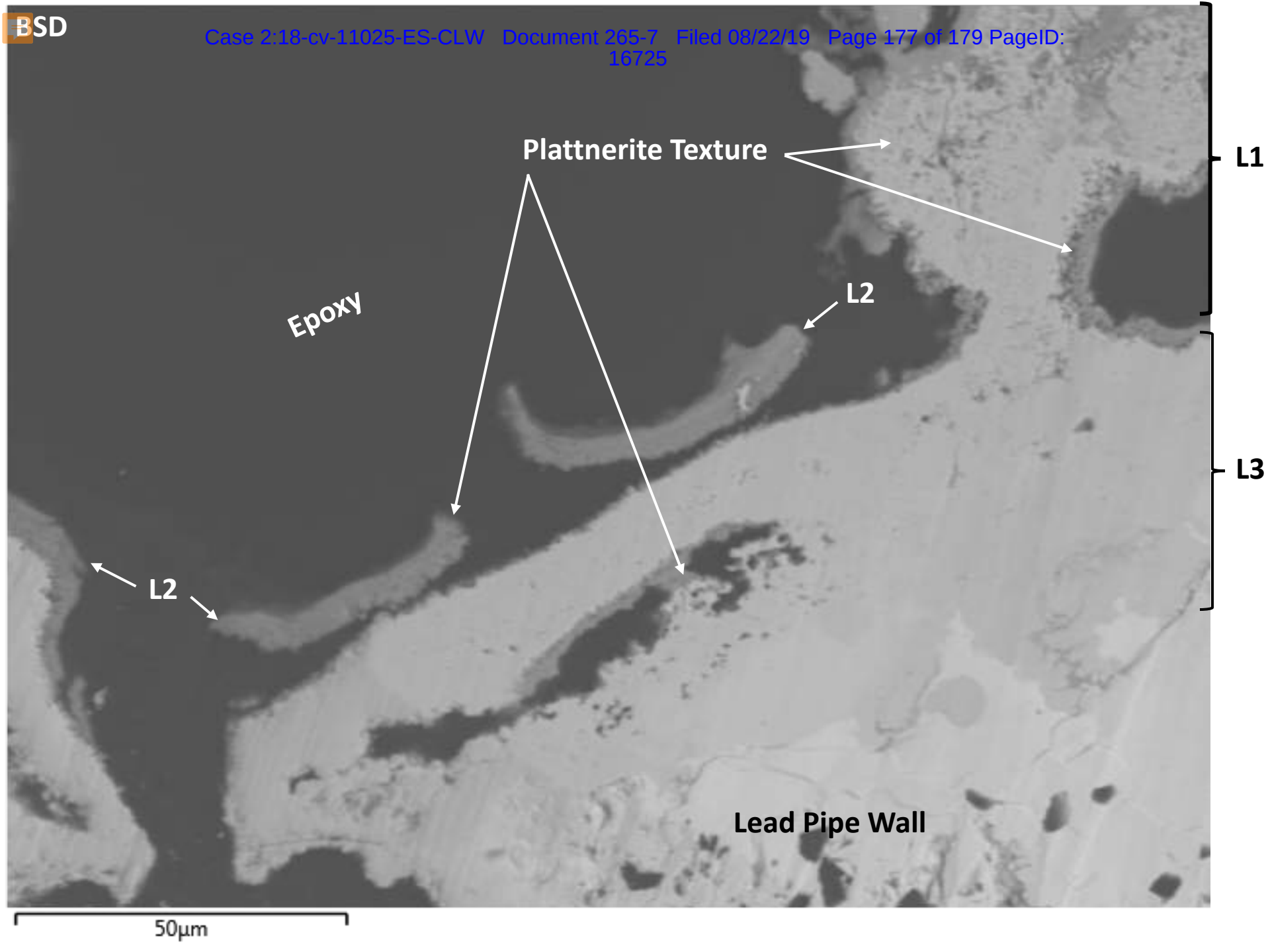
Mn K α 1

50µm

Fe K α 1

50µm

Pb M α 1



Plattnerite Texture

Epoxy

L2

L1

L3

L2

Lead Pipe Wall

50μm



EDS Results, Normalized to 100%

Elemental Concentrations as Average wt%

NJNEPEN1-Pb					
Elements	L1	L2	L3	Upper Tubercle	Lower Tubercle
*C	0.45	0.37	0.43	2.24	0.18
O	23.6	18.3	13.7	12.6	5.5
Mg	0.2	0.2	-	-	-
Al	1.4	0.8	0.3	0.3	0.2
Si	1.0	0.7	-	-	-
P	1.1	0.7	0.1	1.2	0.1
*S	0.11	0.11	0.15	0.67	0.48
Cl	-	-	-	6.3	19.3
Ca	1.2	0.6	-	0.3	-
Mn	7.4	2.7	0.2	0.1	-
Fe	2.3	1.1	0.2	0.2	0.2
Sn	2.8	3.1	1.4	0.1	2.1
Pb	58.6	71.3	83.6	76.1	72.0

*C and S by combustion



**UNITED STATES DISTRICT
COURT FOR THE DISTRICT OF
NEW JERSEY**

NEWARK EDUCATION WORKERS
CAUCUS, et al.,

Plaintiffs,

v.

CITY OF NEWARK, et al.,

Defendant,

**Docket No. 2:18-cv-11025-KSH-
CLW**

Civil Action

**CERTIFICATION OF
SERVICE**

ELECTRONICALLY FILED

I hereby certify that on August 22, 2019, a true and correct copy of the foregoing letter and exhibits was served via the ECF filing system upon the counsel of record, who are registered CM/ECF users.

By: s/ Andrew Reese
Andrew Reese
Deputy Attorney General

Dated: August 22, 2019